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APPLIED MECHANICS REVIEWS

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STABILITY OF LAMINAR FLOWS

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AFTER decades of theoretical and experimental effort, the mechanism of the instability of steady laminar motion is at last reasonably well understood—at least for the case of infinitesimal disturbances. A survey of the theory, including a bibliography, has been published in a recent monograph (23).[1] Other surveys[2] are in preparation. It therefore seems appropriate that in this article we deal with some selected topics on which active research is being done, and on the future outlook, rather than a routine survey. The choice of the material obviously depends somewhat on the point of view of the writer; and important problems might have been omitted.

NONLINEAR OSCILLATIONS

The instability of the steady laminar motion generally leads to another state of laminar motion, steady or unsteady. This is true for infinitesimal disturbances, as well as for disturbances whose amplitude can no longer be treated as infinitesimal. In the latter case, a stationary state may often set in. The regular nature of the flow with oscillations or secondary flow is clearly shown by the calculations of Stuart (41) in the case of the instability of Couette motion with the inner cylinder rotating, and by the measurements of Schubauer and Klebanoff in the case of oscillations in the boundary layer over a flat plate. In either of the above cases, there are some theoretical and experimental results to substantiate the conclusion. In the case of channel flow, only some theoretical results are available (29). In general, detailed results are still lacking regarding the behavior of these oscillations or secondary motions of finite amplitudes, and it seems that further efforts in this direction would be desirable and profitable.

A general study of nonlinear oscillations would, of course, include the problems of fully developed turbulent motion and transition to turbulence. However, it is well known that one can only describe turbulent motion in a statistical manner. Thus, the method used for the detailed treatment of laminar oscillations is bound to become inadequate as one approaches such problems. Landau (17) suggested the following general picture for the transition phenomenon.[3] According to the instability theory, one mode of disturbance becomes amplifying beyond a certain critical Reynolds number R_1. This mode will reach a stable amplitude. At a higher number R_2, this modified laminar motion[4] becomes again unstable, and another mode of disturbance begins to establish itself. Thus, more and more modes appear as the Reynolds number of the flow increases, and the flow becomes turbulent. It would be interesting to find out whether such a conjecture on the transition mechanism is correct or not. It is, of course, possible that the process may hold for one class of problems and does not occur for another class.[5]

The issue has often been raised whether the phenomenon of transition to turbulence is basically two-dimensional or three-dimensional. It is well known that fully-developed turbulent motion is definitely three-dimensional, while in the linear theory of the instability of the parallel flows of an incompressible fluid, two-dimensional disturbances are more unstable. It would be interesting to find out at what stage of the transition mechanism the three-dimensional character begins to play a dominant role.

SOME GENERAL THEORETICAL ISSUES IN THE LINEAR THEORY

In the study of small disturbances, there are still a number of gaps in our theory, and a number of incompletely solved problems.

1. In the development of the theory of stability of parallel flows, the method of asymptotic solution is often used, based on a large Reynolds number. Historically, such methods caused great controversy. In recent years, Tollmien (15), Wasow (46), Langer (18), and Lin (24) have constructed uniformly valid solutions to settle such difficulties. A discussion of the relative merits of these methods may be found in the last-mentioned paper. It is desirable to extend the theory to the case of the boundary layer in a compressible gas flowing at high speeds, both for the sake of the mathematical theory and for getting sufficiently accurate results.

[1] Most of the references cited in the present article appeared after the manuscript of the monograph was completed.

[2] To the knowledge of the present writer, L. Lees and J. T. Stuart are each preparing such an account for publication.

[3] See also Stuart in a paper to be submitted for publication in the Journal of Fluid Mechanics.

[4] The modification of the basic flow may or may not be essential for the second instability.

[5] For some related experimental information, see (38).

In the case of convective instability, higher modes were both studied theoretically and found experimentally. Malkus (49) gave a detailed discussion of this problem in a recent paper in which references to earlier work may be found. Some calculations of higher modes in the case of curved flows were given by Meksyn (28) and by D'Arcy.[6] In the case of parallel flows, it is generally assumed that the higher modes are damped, and they are studied only briefly, if at all, in the earlier work.[7] Grohne (12) recently studied this problem and found that the highly damped solutions show strong oscillations, even at very high Reynolds numbers. This conforms to the results of Wasow[8] and supports the earlier conclusion of the present writer that, even in the inviscid limit, the mathematical solution representing damped and amplified disturbances cannot be regarded as complex conjugates.[9] The physical significance of these damped disturbances has not yet been fully clarified.

2. In applying the theory of stability of parallel flows to jets and wakes, two difficulties are encountered. First, there is as yet no direct justification given for the applicability of the concept of parallel flows. However, it is not likely that serious errors would result from this source. Secondly, there has not yet been developed a proper method for the calculation of the stability characteristics at low Reynolds numbers, since the usual methods for parallel flows are asymptotic.[10] Attempts to treat this and related problems have been made by Curle (5) and by Yih (47). It appears that a direct numerical approach[11] could be used with advantage at such low Reynolds numbers.

3. The stability of the following simple cases remains an unsolved problem: (a) pressure flow through a circular pipe, (b) Couette motion with outer cylinder rotating, and (c) plane Couette motion. Whereas there is every indication of complete stability of these flows with respect to infinitesimal disturbances, this has never been conclusively proved. Nonlinear oscillations provide a reasonable source of the instability of such flows, and it seems worth exploring. Prandtl suggested that the instability of cases (b) and (c) might be found in the velocity distribution prior to the establishment of the steady flow. This suggestion was considered in detail by Schlichting (37). It would be interesting to find out experimentally, for flow between rotating cylinders, whether this or nonlinearity is the real cause. In the case of pipe flow, Tatsumi (42) has shown that there is instability of the flow with respect to infinitesimal disturbances ahead of the region of the parabolic velocity distribution.

[6]See (23)
[7]See (32)
[8]See (25)
[9]See (25)
[10]See (22)
[11]See (44)

SOME SPECIAL PROBLEMS

We discuss below some problems of the instability of fluid motions that deserve further attention. It is obvious that the list is not intended to be complete and is far from being so. For example, problems of flow instability in chemical engineering, paper making, etc., are not included.

1. The stability of the boundary layer is a problem of practical importance. While much is known about this subject (36), (48) there is still much more to be desired in certain important cases. Two such cases are (a) the instability of the boundary layer at supersonic speeds (8), (19), and (b) the instability of three-dimensional boundary layers (11). There has been much recent activity on these subjects, and substantial progress should be expected.

2. Another problem of practical importance is the instability of flow of one fluid over another. This has application both in the problem of the generation of surface waves by winds (26) and in the problem of liquid films in a number of mechanical engineering problems (9). In either case, the disagreement between theoretical and experimental results is not yet understood.

3. The influence of magnetic field on the instability of motions of an electrically conducting fluid has attracted much attention in recent years. In general, it has been found that the effect of the magnetic field is stabilizing. Examples of this effect have been given by Hartmann and Lazarus (14), Murgatroyd (33, 34), Shercliff (39), Stuart (40), and Lock (27) for viscous flow between parallel planes and in pipes, by Chandrasekhar (2) and Lehnert (20) for viscous flow between rotating cylinders, by Chandrasekhar and Fermi (4) for problems of gravitational stability, and Chandrasekhar (1) and Nakagawa (35) for the inhibition of convection in a fluid layer. However, Lehnert (21) recently found, in a suitable experimental arrangement, that an instability of the laminar flow of mercury can be caused by an external magnetic field. Further work in this general area would appear to be much desired.

4. In meteorological and astrophysical problems, the influence of gravitational and Coriolis forces is important. The literature dealing with such problems is again enormous. Examples of recent papers on such topics are those by Taylor (43), Chandrasekhar (3), Kuo (15, 16), and Davies (6, 7). Experimentally, the simulation of atmospheric motions by a rotating "dish-pan" is especially instructive (10). Other references may be found in the papers cited. The study of oscillations in the atmosphere appears to be a very fruitful area for future research.

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"Letters to the Editor" and "Books Received for Review" appear after the reviews

Theoretical and Experimental Methods

(See also Revs. 12, 15, 20, 39, 45, 66, 70, 76, 103, 148, 151, 152, 279, 283, 284, 301, 305, 335, 339, 341)

Book—1. Doetsch, G., Handbook of the LaPlace transformation, II, Application of the LaPlace transformation [Handbuch der LaPlace-transformation, II, Awendungen der LaPlace-transformation], Basel and Stuttgart, Birkhauser Verlag, 1955, 436 pp. DM 56.15.

The first of three volumes contained the fundamental mathematical principles of the Laplace transform. This second and the forthcoming third volumes treat further theory, but mainly applications of the transform. Though examples are taken from many fields of engineering and applied mechanics, the book may prove to be of greatest interest to the mathematician. The three parts into which this volume is subdivided are: Asymptotic representations, convergent representations, and ordinary differential equations. The introduction treats the correspondence of fundamental operations to functions through the Laplace transform and its inverse, and there is a literary and historical note added at the end of the volume as well as an index, a bibliography, and corrections to the first volume. The three main parts of the book are subdivided into chapters dealing with general considerations of asymptotic expansions, Abelian asymptotic expansions, Tauberian expansions, factorial and special series, ordinary differential equations with constant and variable coefficients.

T. P. Torda, USA

Book—2. Tolstow, G. P., Fourier series [Fourierreihen] Berlin, Veb Deutscher Verlag der Wissenschaften, 1955, 300 pp.

See AMR **5**, Rev. 2980.

3. Meecham, W. C., On the use of the Kirchhoff approximation for the solution of reflection problems, *J. rational Mech. Analysis* **5**, 2, 323–334, 1956.

Problem of rigorous justification of Kirchhoff approximation in reflection of radiation from irregular surface is considered. Approximation is developed in systematic way for case of a two-dimensional scalar field, in which field function vanishes at reflection surface, by obtaining integral equation for normal derivative of field function on boundary. First term of iterative solution of this integral equation yields Kirchhoff approximation. Second iterate yields validity criterion for approximation, in terms of maximum slope of function specifying reflection surface, and of product of wave number by minimum radius of curvature of this surface. Development permits computation of correction terms in approximation. It is shown that Kirchhoff assumption yields solution satisfying reciprocity theorem for case of one source.

J. J. Gilvarry, USA

Book—4. Hildebrand, F. B., Introduction to numerical analysis, New York, McGraw-Hill Book Co., Inc., 1956, x + 511 pp. $8.50.

Text is intended to furnish the basis for a one- or (preferably) two-semester introductory course. Author tries to strike a reasonable balance between the treatment of numerical analysis best adapted for automatic computers and that required in desk calculator work; these sometimes require different emphasis, if indeed they are not (occasionally) in outright opposition. Chapter headings give a fair picture of the coverage: Introduction, Interpolation with divided differences, Lagrangian methods, Finite-difference interpolation, Operations with finite differences, Numerical solutions of [ordinary] differential equations, Least-squares polynomial approximation, Gaussian quadrature and related topics, Approximations of various types, Numerical solutions of equations; Appendixes: A, Justification of the Crout reduction; B, Bibliography; C, Directory of methods. Supplementary references and problems are provided at the end of each chapter.

Reviewer is pleased to see the chapter on approximations and the directory of methods (for quick reference), which will be of particular value in applied work. Author has intentionally omitted "advanced course" material: numerical solution of partial differential and integral equations, and modern methods of matrix (partial) inversion.

J. L. Lubkin, USA

5. Nonweiler, T., A method for the numerical evaluation of an integral, *Coll. Aero. Cranfield Rep.* 100, 24 pp., Mar. 1956.

Paper develops the representation

$$\int_0^1\int_0^1 F(x,y)\ln\left|\frac{1}{x-y}\right| dxdy = \sum_{\mu=-n+1}^{n-1}\ \sum_{\nu=-n+1}^{n-1} c_{\mu\nu}F(s_\mu, s_\nu)$$

where $s_\mu = (1 + \sin \mu\pi/2n)/2$, and presents values of $C_{\mu\nu}$ for $n = 2(1)6$. Two particular applications to supersonic wave-drag problems are discussed. See, for example, AMR **3**, Rev. 529.

Y. L. Luke, USA

6. Mitchell, A. R., Round-off errors in implicit finite difference methods, *Quart. J. Mech. appl. Math.* **9**, 1, 111–121, Mar. 1956.

Symmetrical and asymmetrical implicit finite difference replacements involving a variable parameter a and a variable mesh ratio s are considered for the heat conduction and wave equations, and expressions obtained for the round-off errors.

It is found that the stable backward difference replacements, four-point for the heat-conduction equation and five-point for the wave equation, give rise to minimum round-off errors.

From author's summary

7. Hermann, P. J., Starks, K. H., and Rudolph, J. A., Basic applications of analog computers, *Instrum. and Automat.* **29**, 3, 464–469, Mar. 1956.

The industrial engineer can use the analog computer in one of three ways—using a mathematical-equation description of his problem, using a transfer-function description of his problem, or by establishing a computer circuit that acts like the elements in his problem. The second approach is of the greatest importance to industrial process control—and several examples are described.

From authors' summary

8. Macduff, J. N., Principles and design uses for analog simulators. Part I, Analog components and mathematics, *Mach. Design* **28**, 16, 86–90, Aug. 1956.

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10. Pearson, C. E., Note on linear programming, *Quart. appl. Math.* **14**, 2, 205–206 (Notes), July 1956.

11. Kahn, H., Use of different Monte Carlo sampling techniques, Rand Corp. Rep. P-766, 40 pp., Nov. 1955.

The prime emphasis of this 40-page report on the Monte Carlo method is reduction of variance, in order that the final results may be obtained more accurately and with less calculation. Importance Sampling involves the use of weighting factors in such a way that sampling error is reduced and then removing the bias to obtain the desired results. Russian Roulette and Splitting employs supplementary probability games which create distinctions between "interesting" and "uninteresting" outcomes and concentrates major efforts on the former. The use of Expected Values enables one to avoid Monte Carloing a problem all the way by using analytical solutions for easier portions and strictly Monte Carlo methods for the more difficult areas. Other less effective methods of variance reduction are discussed, viz., correlation and regression, stratified sampling and systematic sampling.

The second part of the report discusses the evaluation of definite integrals by Monte Carlo methods, with special reference to the details of applying the various variance reduction methods. Examples mentioned include nuclear shield penetration, vulnerability weapons studies, and Operations Research queuing problems.

Throughout the paper remarks are encountered which show that its author has been exposed to actual usage of the methods, in particular the closing observation that a man mainly interested in the problem itself is preferable to one who is mainly interested in statistics. The paper, however, is of greater interest to the latter.

E. C. Varnum, USA

Mechanics (Dynamics, Statics, Kinematics)

(See also Revs. 30, 63, 71, 192, 353)

Book—12. Szabo, I., Higher technical mechanics [Höhre Technische Mechanik], Berlin, Springer-Verlag, 1956, xii + 472 pp. DM 31.50.

According to the curriculum of the Technical University of Berlin, the students of mechanical, electrical, and civil engineering and of mathematics have a four-semester course on technical mechanics with four lecture periods and two problem periods a week. In addition, in the third and fourth semester there is an optional course, two periods a week, on selected topics of mechanics.

The book under review covers the material discussed in the second half of the four-semester course, the first part being covered in author's "Introduction to technical mechanics" [AMR **8**, Rev. 1905]. Although the present book is a continuation of the latter, it is complete in itself for anyone who is familiar with the basic concepts and laws of mechanics. A novel and highly laudable feature of the book is author's aim to bridge, at least to some extent, the still existing gap between theoretical mechanics as it is taught at the universities on the one hand and technical mechanics as taught at the technical universities on the other hand. In reviewer's opinion, author has been very successful in mathematizing technical mechanics and in trying to bring it up to the needs of a modern engineer, and hence making it also more appealing to mathematicians. In cases where a rigorous solution cannot be readily obtained, approximate methods have been developed, or at least indicated. To a certain extent the book can also be used as an up-to-date reference book.

Contents consist of 23 sections grouped into four chapters, each section being subdivided into three to ten subsections.

The first chapter (sections 1–8, 132 pages) is concerned with the development of mechanics from the point of view of statics. Accordingly, the principle of virtual work is formulated as a general and basic law of statics. Statics and dynamics are then formally united by the d'Alembert principle. The effectiveness of these two principles is shown in deducing the Rayleigh-Ritz method from the principle of virtual work and the Lagrangian equations and the Hamilton principle from the d'Alembert principle. Numerous applications are made of these principles to statics and dynamics of rigid and elastic bodies (Theorems of Castigliano, Rayleigh-Ritz's method, vibrations of strings, membranes and bars, motion of a rigid body in space, gyroscope). The chapter concludes with an introduction to the calculus of variations and its applications to mechanics (Ritz's method for determination of eigen values, Rayleigh's quotient).

The most extensive of all the four chapters of the book is the second (sections 9–15, 187 pages) which concerns selected topics from the theory of elasticity: plane stress, axially symmetric stress distribution (Airy's and Love's stress functions, pressure distribution between two bodies in contact and impact of elastic bodies according to Hertz, thermal stresses), Kirchhoff's theory of plates, followed by an introduction to the theory of shells, torsion of bars and beams (Saint-Venant's theory, membrane analogy of Prandtl, hydrodynamical analogies), elastic instability problems (buckling of columns, circular tubes, plates and circular cylindrical shells, tilting of trusses).

The third chapter deals with the theory of plasticity (Sections 16–17, 60 pages). After a brief mention of the works of Saint-Venant, Levy, von Karman, von Mises, Prandtl, Reuss, Hencky, Nadai, applications are made to plastic bending and plastic torsion of beams. Also the buckling theories of Engesser, von Karman and Shanley are given.

The last (fourth) chapter (sections 18–23, 83 pages) is concerned with fluid dynamics (liquids and gases). The theory of perfect fluids (von Helmholtz theorems, potential flows, method of conformal representation, theorem of Kutta-Joukowski, profiles) is followed by the theory of viscous fluids (Navier-Stokes equations, Prandtl's boundary-layer theory), and the chapter terminates with the theory of ideal gases (Mach number, shock waves, supersonic flow past thin profiles, bodies of revolution of smallest resistance).

The book contains 73 illustrative problems, some of a rather complicated nature, which are appended to the corresponding sections and which are completely solved. In numerous footnotes, reference is given to books and papers of importance. The volume concludes with common author and subject index. The figures,

paper, and printing are excellent and customary to the Springer Publishing House. Reviewer highly recommends the study of this most valuable book to mathematically-minded engineers.

E. Leimanis, Canada

13. **Martin, G. H., and Spotts, M. F., An application of complex geometry to relative velocities and accelerations in mechanisms,** ASME Semiann. Meet., Cleveland, O., June 1956. Pap. 56-SA-32, 15 pp.

As authors are aware, use of complex plane method for velocity and acceleration analysis in link work is not new, but it is refreshing to find a paper on it in English. After general explanation illustrated by four-bar linkage, authors show application to complex multibar linkages and to direct contact mechanisms. Method is of real advantage in some of these. Even in simple cases where usual graphical methods are quicker for individual positions, complex method leads to time saving by routine tabulation for large numbers of positions. This might also be mechanized in suitable cases.

E. M'Ewen, England

14. **Kappler, P., General methods of calculating cam curves—if the mass of the mechanism (as reduced to the cam follower) varies and if the follower is not concentric** (in German), *Maschinenbau-Technik* **5,** 3, 134-140, Mar. 1956.

Difficulties encountered due to vibration and chattering of cam followers have, in the past, been met by the use of closed cams. These require close manufacturing tolerances and do not eliminate the cause of the trouble. It is pointed out that the common method of designing a cam on the basis of minimum acceleration of the follower is inadequate. It is shown that transfer of energy into and out of the follower system is a more appropriate criterion, and a complete discussion of a semigraphical method of computation, together with examples, is given.

C. E. Balleisen, USA

15. **Speiser, A. P., Coordinate systems in fire control computers** (in German), *ZAMP* **7,** 1, 1-16, 1956.

Different ways of calculating are described. Choice of coordinate system is discussed for different parts of the calculation. This choice depends not only on the type of computing elements used, but also on the formulas, by which the geometric and ballistic computations are to be done. Accuracy to be expected of an instrument depends partly on the coordinate systems selected at every point of the computing process.

Author's conclusions imply nothing new. They are well known by those who are engaged with anti-aircraft gun development.

Å. Silfverhielm, Sweden

16. **Lawden, D. F., Transfer between circular orbits,** *Jet Propulsion* **26,** 7 (part 1), 555-558, July 1956.

A solution is given to the problem of transferring a rocket from a circular orbit about one planet into another about a second planet with minimum expenditure of fuel. The planetary orbits are assumed to be coplanar and the longitudes of the planets in their orbits at the instants of departure and arrival of the rocket are supposed to be specified. The case of transfer between the Earth and Mars is taken as a numerical example of the general theory.

From author's summary

17. **Howell, J. D., The geometry of belt and chain drives,** ASME Semiann. Meet., Cleveland, O., June 1956. Pap. 56-SA-41, 23 pp.

Problems involving the geometry of belt and chain drives have always been considered difficult and tedious because of the complexity of the standard formulas connecting center distance, pulley diameters, and belt length. After demonstrating the derivation of the standard formula, new formulas are derived, using functions of the involute, which greatly simplify the calculation of many such problems.

From author's summary

18. **Havely, T. W., Phalen, C. A., and Bunnell, D. G., Cam and tappet surface distress,** *SAE Trans.* **63,** 204-210, 1955.

Servomechanisms, Governors, Gyroscopics

(See also Revs. 39, 247, 261, 263, 302, 303, 304, 305)

Book—19. Oldenburger, R., editor, Frequency response, New York, Macmillan Company, 1956, xii + 372 pp. $7.50.

Papers and addresses on automatic control presented at the 1953 ASME "Frequency response colloquium," with discussion, criticism, and bibliography, plus ten additional articles, two of which were originally published in Russian. Introduction by Oldenburger gives a clear synopsis of the book.

I. *Fundamentals.* NYQUIST explains in a few words the circumstances which led him to his well-known paper of 1932; HALL adds the early history of the frequency-response field. MACMILLAN presents a brief survey of the frequency-response method and several related techniques of analysis for servomechanisms. The following topics are considered: the different forms of the frequency-response diagram; the generalization to damped oscillations; stability and relative stability charts; the phase angle and roots loci; the frequency-response approach to nonlinear systems; current research and future prospects. OLDENBURGER presents standards for the presentation of frequency response data, recommended by the A.S.M.E.-I.R.D. Dynamic Systems Committee. Basic design criteria show that control design can be reduced, at least in rough analysis, to simple properties of curves; from the slope of one such curve the designer can often say whether the controller will be stable. FUCHS gives a bibliography of the frequency-response method, containing 300 items. MACMILLAN discusses design of speed-regulating systems. The derivation of transfer functions is described and applied to a more detailed study of a simple gas-turbine governor.

II. *Frequency-response aids.* IZAWA describes computational aids. A special slide rule for magnitude ratios and phase angles in certain systems. A nomogram for deriving closed-loop frequency-response curves from such for the open loop. CLAIR, ERATH, GILLESPIE give data on pneumatic, mechanical and electrical sine wave generators to be used for the taking of frequency-response data.

III. *Servo, airplane and power system applications.* HELM gives the frequency-response approach to the design of a mechanical servo, illustrated by the actual design of an automatic contour-following lathe. HALL discusses application of frequency response to hydraulic control systems; the problem is studied by a linear approximation. Example: a valve motor system, electrical analogs. OJA applies the frequency-response method to the study of turbine regulation in the Swedish power system. SMITH, TRIPLETT discuss methods for obtaining airplane frequency-response characteristics from transient flight measurements. The short-period pitch response to an elevator deflection. Numerical example.

IV. *Process control.* JANSSEN describes the causes of the gap between theory and practice; the "philosophy" of control. Control-system behavior expressed as a deviation ratio. Only graphical means are used. AIKMAN presents frequency-response analysis of two types of chemical plant units and the adjustments of the automatic controllers. An approximative calculation method. KRAMERS, ALBERDA show possibilities of frequency response for continuous processes in chemical engineering. The distribution of residence times in continuous-flow systems is deduced from experiments on the behavior of longitudinal gradients on their course through the system. EYKMAN, VERHAGEN discuss response and

phase-lag of thermometers. Calculation results are compared with experimental data.

V. *Transient response.* LEONHARD gives novel methods of calculating the relations between frequency and transient responses. One of the three examples deals with the computing of the transfer function of a system represented by a partial differential equation, the Laplace transform of which is taken. EVANS shows the use of zeros and poles for frequency response. Roots of the characteristic equation are computed graphically in the complex plane. LEES shows that, by choosing appropriate standard contours on the complex plane, the dynamic characteristics of a system are estimated by means of the mapping theorem (a corollary of Cauchy's residue theorem) which makes use of two planes. Two examples: polynomials with constant and with adjustable coefficients.

VI. *Optimum controls.* OLDENBURG, SARTORIUS discuss common aspects of the problems encountered in achieving optimal adjustment. The output behavior follows a normalized disturbance of the equilibrium. A practical method is suggested. WESTCOTT gives two methods of synthesizing feedback systems in which stability considerations are qualified by an overriding limit on power demand. The second method is based on the calculus of variation and the use of a Lagrangian multiplier. An example illustrates the desirability of allowing a finite time delay between input and output.

VII. *Nonlinear techniques.* GOLDFARB discusses some nonlinear phenomena in regulatory systems. Approximate solution of the problem of limited motion movements. The concept of the equivalent admittance of a nonlinear element. Conditions of occurrence of self-excited oscillations. LOEB writes on "filtered nonlinear servos," i.e., servos where the signal undergoes a filtering effect from a linear part of the device. Phenomena such as Coulomb friction and gear backlash are dealt with. A general stability criterion is derived and it is shown how NYQUIST'S appears as a particular case. CHESTNUT gives approximate frequency-response methods for representing saturation and dead band. THOMAS presents a method of analyzing closed-loop systems under cyclic motion of the self-sustaining type, as caused by the presence of dead band. Stability criteria.

VIII. *Sampling controls.* TSYPKIN, in his paper, shows under what conditions intermittent regulation improves the properties of systems, as compared to continuous regulation. BARKER describes the manipulation of samples, studied by a transform method analogous to LAPLACE'S. A list of transforms is given.

IX. *Statistical methods.* PELEGRIN gives a study of a system subjected to steady sine-wave disturbances. A particular servo-circuit is computed by statistical methods and the output autocorrelation function of a relay obtained.

O. Bottema, Holland

20. Macmillan, R. H., A graphical method for the analysis of piecewise linear control systems, with particular application to relay controls, ASME Semiann. Meet., Cleveland, O., June 1956. Pap. 56-SA-17, 10 pp.

Instead of using the powerful phase-plane method for studying piecewise linear control systems of second order [see for instance: I. Flugge-Lotz, Discontinuous automatic control, Princeton University Press, 1953; AMR **7**, Rev. 3114], author develops "characteristic curves" for the study of such systems. These curves allow the piecewise construction of the output curve as a function of time. This graphical method is simple only in the case where the switching of the relays depends only on the error, but not additionally on the rate of change of the error. The influence of imperfections (delay of switching, dead zone, etc.) is studied in detail. In an appendix, B. M. Brown shows the relation between points of the characteristic curves and the phase-plane representation of motion.

I. Flugge-Lotz, USA

21. Reed, W. E., Pneumatic control of a turbojet variable nozzle, *Control Engng.* **3**, 10, 92–99, Oct. 1956.

22. Decker, J. L., The human pilot and the high-speed airplane, *J. aero. Sci.* **23**, 8, 765–770, Aug. 1956.

23. Bellman, R., Glicksberg, I., and Gross, O., On the "bang-bang" problem, *Quart. appl. Math.* **14**, 1, 11–18, Apr. 1956.

Authors investigate the problem of optimizing the forcing terms of a "bang-bang" controlled system in such a manner that the system returns to rest after a minimum number of switching points. The investigation is restricted to stable systems represented by linear differential equations with constant coefficients.

A mathematical proof is given (1) that such an optimum exists, and (2) that for a nonoscillatory system of n degrees of freedom the optimum can be selected so that not more than $(n - 1)$ switching points occur.

The method and its use are illustrated on an example of two degrees of freedom.

G. W. Braun, USA

Book—24. Merkin, D. R., Gyroscopic systems [Giroskopicheskiye sistemy], Moscow, Gos. Izdat. Tekh.-Teor. Lit., 1956, 299 pp. 9r.45k.

This monograph goes to the basis of the theory of gyroscopic systems as indicated by W. Thomson and P. Tait in their "Treatise on natural philosophy" (Cambridge, 1879). This conception treats, from a general viewpoint, the role of gyroscopic forces occurring in the equations of motion for mechanical systems with gyroscopes. One of the most important facts in studying such questions lies in the possibility of replacing the exact equations of gyroscopic systems by simpler relations in order to facilitate the solution of a problem. Nevertheless, such a simplification can be made only under special conditions and one has always to estimate the degree of resulting approximation. Book pays special attention to considerations of this kind.

Content is divided into six chapters and an appendix. The chapter titles will give a more detailed idea of the subject: I. Gyroscopic forces (general definition, the most important classes of mechanical systems with such forces). II. Gyroscopic forces depending upon parameters (reader's attention is called especially to the necessary conditions for simplifying the basic equations). III. Motion of systems subjected only to gyroscopic forces (stability questions, possibility of simplified solutions, dissipative forces). IV. Influence of gyroscopic forces on the motion of conservative systems. V. The same for nonconservative cases. VI. Steady motion of gyroscopic systems (problems with cyclic coordinates, conditions of stability, motion of simplified systems). Appendix deals with the stability questions for mechanical systems having multiple and purely imaginary characteristic numbers. Book ends with a good list of literature (57 sources, both Russian and non-Russian) followed by a carefully made index of matters treated.

Paper is good, print excellent. There are 37 instructive figures throughout the text. Reading presupposes familiarity with a good course of theoretical mechanics and with the fundamentals of the theory of stability. We highly recommend this valuable book with its modern way of presentation to specialists working in gyroscopics and theoretical mechanics.

V. Vodicka, Czechoslovakia

25. Draper, C. S., Wrigley, W., and Grohe, L. R., The floating integrating gyro and its application to geometrical stabilization problems on moving bases, *Aero. Engng. Rev.* **15**, 6, 46–62, June 1956.

Paper reviews the essential functional features of geometrical stabilization systems and describes the performance characteristics of gyro units used in these systems.

From authors' summary

26. **Rohmann, C. P., and Grogan, E. C., On the dynamics of pneumatic transmission lines,** ASME Semiann. Meet., Cleveland, O., June 1956. Pap. 56-SA-1. 15 pp.

Paper is an analytical and experimental treatment of the dynamics of pneumatic transmission lines. It is assumed that resistance, inertance, and capacitance parameters are uniformly distributed throughout the line. The analysis is a linearized one and input signals are limited to small values ($\leq$ 1.2 psi peak-to-peak). Authors place emphasis on driving-point impedance and short runs where resonances occur . Data on this aspect of the subject has not previously appeared in the literature. Authors obtain some useful results. Agreement between theory and experiment is good.

S. Z. Dushkes, USA

Vibrations, Balancing

(See also Revs. 9, 348)

Book—27. **Den Hartog, J. P., Mechanical vibrations,** 4th ed., New York, McGraw-Hill Book Co., Inc., 1956, xi + 436 pp. $9.

This well-known text book celebrates its 22nd birthday by appearing in its fourth edition and this fact in itself provides ample proof of the excellence of its quality. It is fatally easy for the author of a popular text to become complacent and to be satisfied with drawing his royalties, leaving the content of the book virtually unchanged from one edition to the next. Professor Den Hartog has not succumbed to this temptation and although the number of pages in the present edition is a little less than in the second edition of 1940, the amount of print per page has been increased. In almost every chapter, there are some deletions of out-of-date matter in favor of additions concerned with more recent developments; for example, nonlinear vibrations and the application of the von Karman vortex street. From the undergraduate's standpoint, one important gain is the increase in the number of problems from 114 in the second to 233 in the present edition.

In this country, two of the hardest tasks of a University teacher are to persuade his students, first, to build up a private library and, second, to consult and digest original papers. It is partly in connection with the second difficulty that I regret the omission from the present edition of a bibliography of about 3½ pages which appeared in the 2nd edition. As the author points out in the preface, the subject of mechanical vibrations has grown out of all knowledge during the past 20 years and the literature has almost gone out of hand. Nevertheless, there remain a number of classical papers which should be compulsory reading for every undergraduate; the author, with his expert knowledge of the subject, would do a real service to teachers and students alike if he were to include a basic bibliography in the next edition of his book.

With this single reservation, this text will continue to fulfill its purpose of presenting the fundamentals of the subject in an attractive and efficient manner to undergraduate and practicing engineers and physicists.

R. M. Davies, Wales

28. **Jeffreys, H., A modification of Lagrange's equations for small oscillations when some natural frequencies are high,** *Quart. J. Mech. appl. Math.* **9**, part 2, 247–248, June 1956.

29. **Cahill, W. F., and Levy, S., Computation of vibration modes and frequencies on SEAC,** *J. aero. Sci.* **22**, 12, 837–842, Dec. 1955.

A description is given of several codes developed for use in the Standards Eastern Automatic Computer for computing the free vibration modes and frequencies of aircraft structures. The codes are general in nature and apply without modification to any aircraft structure whose influence coefficients, mass distribution, and geometry are specified. The codes are applicable when no more than 63 mass points are needed to define the displacement of the half-wing. In an example with seven mass points along the fuselage axis and 24 mass points for each half-wing, the computing time for the first six symmetric and the first six antisymmetric modes was 6 hrs.

From authors' summary

30. **Waters, H., Vibrations of elastic systems, Parts I, II,** *Civ. Engng. Lond.* **51**; 597, 297–300, Mar. 1956; **51**, 600, 667–670, June 1956.

Articles are an elementary account of the vibrations of strings, membranes, bars, and plates. Each problem is dealt with by the fundamental and energy methods. In introductory section on the single mass-spring system, author gives result for solid friction using equivalent viscous damping which gives no solution when exciting force is less than $4/\pi \times$ *frictional force*. It can easily be shown, however, that a steady state is possible in this regime.

K. H. Griffin, England

31. **Lin, T. C., and Morgan, G. W., A study of axisymmetric vibrations of cylindrical shells as affected by rotatory inertia and transverse shear,** *J. appl. Mech.* **23**, 2, 255–261, June 1956.

See AMR **9**, Rev. 1722.

32. **Geiger, J., A more accurate method for the calculation of bending vibration of frames** (in German), *ZVDI* **98**, 7, 261–266, Mar. 1956.

The fundamental symmetric and the fundamental unsymmetric mode of flexural vibration of a portal or U-frame are determined. The conventional Bernoulli-Euler differential equation is solved by separation of variables, mass and stiffness of girder and columns being taken as uniformly distributed although not necessarily equal. The influence of shear deformation and longitudinal stretching of the members is estimated. Experiments confirming the analysis are described.

Author has been at considerable pains to put his work in a form directly usable by designers who encounter U-frames in transformers, turbine foundations, mill building frames, and elsewhere. All need for dealing directly with the transcendental frequency equation is removed by a set of graphs. These give not only the two fundamental frequencies but also the effect of changes in the cross-section shape.

Use of the words "more accurate" in the title refers to a previous solution in which the frequency of the lowest symmetrical mode was obtained by Rayleigh's method. A number of unfortunate errors arise through the printer's having separated the last letter in the word 'cosh' and having printed it in the same font as a symbol representing a certain dimension. There is an obvious misprint in equation [1].

L. E. Goodman, USA

33. **Kopzon, G. I., Vibration of thin-walled elastic bodies in a gas flow** (in Russian), *Dokladi Akad. Nauk SSSR (N.S.)* **107**, 2, 217–220, 1956 (translated from Russian by M. D. Friedman, 572 California St., Newtonville 60, Mass., 6 pp.).

Rather sketchy formulation of panel flutter problem for cylindrical shell. Drag coefficient, but not stability criterion, is calculated. Reviewer notes author's assumed form of aerodynamic pressure is insufficiently general at subsonic speeds. (For a more detailed treatment of flutter problem, see: J. W. Miles, "Supersonic Flutter of a Cylindrical Shell," Ramo-Wooldridge Rep. GM-TR-32, May 25, 1956; *J. aero. Sci.* (in press).)

J. W. Miles, USA

34. **Kopzon, G. I., Vibrations of a shallow wing shell in a gas flow** (in Russian), *Dokladi Akad. Nauk SSSR (N.S.)* **107**, 3, 377–380, 1956 (translated from Russian by M. D. Friedman, 572 California St., Newtonville 60, Mass., 6 pp.).

Applies results of preceding paper to panel vibration of wing having rectangular platform.

J. W. Miles, USA

35. **Leone, P. F., Mechanical stability of two-bladed cantilever helicopter rotor,** *J. aero. Sci.* **23,** 7, 633–638, July 1956.

The mechanical stability or "ground resonance" characteristics of helicopter rotors has been the subject of many fine papers but nevertheless still remains as one of the problem areas of rotor design. Author treats the subject of a two-bladed rotor whose hub is mounted upon isotropic elastic supports. The equations for kinetic and potential energies of the blades and hub are shown and the equations of motions are derived. Author compares his results with those of Feingold [*NACA ARR* 31, Sept. 13, 1943] and Coleman [*NACA ARR* 3G, July 29, 1943]. The effects of root torsion-tension straps are shown in the appendix.

R. A. Young, USA

36. **Kanai, K., An explanation for the ground vibration caused by periodically exerted force,** *Bull. Earthq. Res. Inst., Tokyo Univ.* **33,** part 3, 283–286, Sept. 1955.

Relation of distance to amplitude of ground vibration caused by periodically exerted force is generally shown by a sinuate decay curve which has been considered to be superposition of two direct waves of different velocity. Author shows other types of decay curves to which afore-stated consideration is not applicable and presents a new theory of more general use which considers amplitude of ground vibration being given as superposition of direct waves and those reflected at boundary of lower layer. Possibility of determining underground structures from decay curve is also suggested.

K. Kasahara, Japan

37. **Takahasi, R., A short note on a graphical solution of the spectral response of the ground,** *Bull. Earthq. Res. Inst., Tokyo Univ.* **33,** part 3, 259–264, Sept. 1955.

Propagation of elastic waves of infinite trains in the ground normal to multilayered system can be solved by method of position angle which is used to study propagation of electric waves along transmission line with one end open. Graphical solution is presented for soil layers of no viscous damping (i.e., problem of stationary oscillation) to draw spectral response of surface motion to amplitude of vibration at boundary of bedrock.

K. Kasahara, Japan

38. **Paslay, P. R., and Slibar, A., Optimal design of a Salomon vibration damper** (in German), *Ing.-Arch.* **24,** 3, 182–187, 1956.

Damper under consideration consists in principle of a cylinder rolling in a somewhat greater cylindrical hole in crank counterweight of a crankshaft. Linear theory is well known. Authors deduce nonlinear differential equations governing vibrations. No "equivalent mass" can transform equations into those of centrifugal pendulum. Equations are solved by iteration. Authors compute important components of a Fourier series representing relative angular speed difference. First tuning formula is the same as in linear theory. Notwithstanding correct tuning in linear case, dimensions can be such that first harmonic is in resonance. Authors give relation between construction parameters in order to minimize amplitude of first harmonic.

W. L. Esmeijer, Holland

39. **Hayes, E. J., Viscous damper design refinements for servomechanisms,** ASME Semiann. Meet., Cleveland, O., June 1956. Pap 56-SA-40, 13 pp.

Some of the parameters that limit the linearity of the liquid viscous dampers were investigated, and criteria for the design of dampers were determined, such as sealing, adjustment of damping, maximum viscosities, and minimum clearance.

Formulas describing damping coefficient as a function of geometry and viscosity were derived analytically for a cylindrical-type damper and empirically for a disk-type damper.

A machine has been built for the purpose of testing rotary viscous dampers at distinct steps of angular velocities, and for the purpose of obtaining the damping sinusoidally by the logarithmic decrement method. A gravity method was also built and used for large number of tests. Three different types of dampers, namely, disk, multiple-disk, and cylindrical, were designed, built, and tested.

From author's summary

40. **Vocke, W., Evaluation of the Geiger diagram in the measurement of torsional vibration of engines** (in German), *Machinenbau-Technik* **5,** 6, 288–292, June 1956.

Author describes use of torsiographs and analysis of torsiograms to determine amplitudes, stresses, mode shapes, and damping. He illustrated usefulness of prepared graphs of superimposed harmonic components for analysis of torsiograms. Manley's "waveform analysis" and David W. Taylor Mod. Basin Rep. 794 also give prepared graphs for visual waveform analysis. No new material is given in the article.

N. H. Jasper, USA

41. **Nacinante, J. A., The measurement and isolation of vibration,** *J. Instn. Engrs. Austral.* **27,** 12, 323–337, Dec. 1955.

Paper is confined to seismic operating systems. Vibratory motion may be converted and indicated by mechanical, optical, or electrical means. Several recent seismic instruments developed at the Division of Metrology, C.S.I.R.O., are presented. Author discusses isolation problems by means of examples from his own experiences. Engineers, as well as the vibration specialist, will find paper stimulating and a useful survey. It ends with a comprehensive bibliography.

P.-P. Heusinger, Germany

Wave Motion in Solids, Impact

(See also Revs. 3, 37, 127, 338)

42. **Kasahara, K., Experimental studies on the mechanism of generation of elastic waves, Part V.,** *Bull. Earthq. Res. Inst., Tokyo Univ.* **33,** 3, 411–417, Sept. 1955.

Paper concerns author's continued experiments on behavior of elastic solids near source of disturbance [for preceding papers in the series see AMR **7,** Rev. 2094; **8,** Rev. 312].

A straight rubber tube was embedded in agar-agar jelly with its axis parallel to surface such that air could be pumped in. Pressure in tube could be raised impulsively so that stress waves were excited within jelly from this "line-source." Vertical displacements of surface of jelly were recorded electrically at various distances from epicenter. Records were taken for several depths of focus.

Some attempt is made to compare experimental results with theoretical predictions of Nakano [*Japan. J. Astron. Geophysics* **2,** p. 233, 1925] and recent work of Lapwood [AMR **3,** Rev. 2594]. However, reviewer believes that importance of this paper lies in the interesting experimental techniques and results that are described.

R. E. D. Bishop, England

43. **Alverson, R. C., Impact with finite acceleration time of elastic and elastic-plastic beams,** ASME Nat. Appl. Mech. Conf., Urbana, Ill., June 1956. Pap. 56-APM-14, 5 pp.

Paper examines behavior of an elastic-plastic beam, subjected to impact at the midpoint, which experiences constant acceleration for a small finite time and constant velocity thereafter. Assumption is made that one plastic hinge develops at mid-cross section. Solution on this basis is found to be appropriate when work done in plastic deformation is less than or equal to the maximum elastic strain energy of the beam. This limited range of validity precludes any attempt to assess the errors involved in rigid-plastic analysis of the same problem, which becomes appropriate when work done in plastic deformation is greater than the maximum elastic strain energy.

The mathematical analysis is appended.

M. J. P. Musgrave, England

44. **Seiler, J. A., Cotter, B. A., and Symonds, P. S., Impulsive loading of elastic-plastic beams,** ASME Nat. Appl. Mech. Conf., Urbana, Ill., June 1956. Pap. 56–APM–17, 7 pp.

A simply supported beam of ductile material is subjected to impulsive loading which gives rise to a velocity varying sinusoidally along the length.

Two solutions are presented: (1) elastic-plastic, assuming a single hinge; (2) rigid-plastic, assuming a central plastic section. These give seriously different estimates of the central angular deformation. It is shown that estimate (1) is very close to that from a rigid-plastic analysis assuming a single hinge.

Authors conclude that an elastic-plastic solution assuming a central plastic section should be attempted.

M. J. P. Musgrave, England

Elasticity Theory

(See also Revs. 59, 61, 73, 85, 90, 91, 113, 294)

45. **Campanato, S., Boundary-value problems in two-dimensional elasticity** (in Italian), *R. C. Semin. mat. Univ. Padova* **25**, 307–342, 1956.

Author introduces the partial differential equations for the equilibrium of a plane, elastic, isotropic, and homogeneous body and examines first the case in which the stress is assigned on the boundary. He transfers the problem to a system of ordinary integral Fredholm's equations: this is obtained by modifying Somigliana's matrix so that it is possible to avoid principal Cauchy integrals in the limit formulas for the potentials on the boundary. The existence theorem is also obtained for given data on the boundary, which are only summable. Potentials of simple and double surface layer with only summable density and momentum are studied.

Assigning the stress on a part of boundary and the displacement on remaining part, completeness theorems are given for the vectors which transfer the problem to systems of integral Fischer-Riesz equations.

R. Nardini, Italy

46. **Olszak, W., On a correlation between the states of stress in the theory of elasticity** (in Polish), *Spraw. Polsk. Akad. Umiej.* 52, 6, 501–503.

Paper is a continuation of the author's studies (1934, 1936) on some correlations between states of stress in two-dimensional problems of the theory of elasticity, especially in doubly- and multiply-connected bodies, for special types of loading. Simplification when applying author's "generalized Poisson's ratio" [AMR **3**, Rev. 2209] is shown. This ratio has been used since by other authors [e.g., M. T. Huber, AMR **2**, Rev. 1367]. Practical applications for both theoretical and experimental studies [e.g., Leon and Willheim, Siebel and Kopf, etc.] are indicated.

J. Nowinski, Poland

47. **Caprioli, L., On the criteria of existence of strain energy** (in Italian), *Boll. Un. Mat. Ital.* **3**, 10, 481–483, 1955.

It is shown that the existence of a strain-energy function for a linear or nonlinear elastic material is a consequence of the following assumptions: (1) the stress tensor depends exclusively on the strain tensor, and (2) the work necessary to produce any deformation starting from the stress-free state is non-negative. Possible applications of the underlying mathematical lemma to electromagnetic theory are indicated.

W. Prager, USA

48. **Thadani, B. N., Distribution of deformation method for the construction of influence lines,** *Civ. Engng., Lond.* **51**, 600, 645–649, June 1956.

Paper presents a procedure for the construction of influence lines based on Dr. C. V. Kloucek's method of distribution of deformation for the solution of indeterminate structures. As far as the author is aware, this method of drawing the influence lines for statically indeterminate frames has not been described previously. The present paper is concerned chiefly with prismatic structures, but the method can easily be extended to nonprismatic structures, as is explained at the end of the article. For nonprismatic structures, however, use must be made of certain tables or graphs giving the properties of members with variable moments of inertia.

From author's summary

49. **Braun, O., Examples of simplified computation of the loading terms in the elasticity equations,** *J. Boston Soc. civ. Engrs.* **43**, 2, 128–141, Apr. 1956.

50. **Petitdidier, M., Surface limits of elasticity and rupture** (in French), *Rev. Métall.* **52**, 10, 764–770, Oct. 1955.

51. **Hersch, V. J., Pfluger, A., and Schopf, A., Simultaneous difference method for the estimation of torsional stiffness and the capacity on both sides** (in German), *ZAMP* **7**, 289–112, 1956.

Paper treats a method for determining the torsional stiffness (electrical capacity) on both sides of a prismatic rod with simply-connected cross section. Author first replaces the variational principles (Dirichlet and Thomson) with two finite difference problems able to estimate a lower bound (and an upper bound) for the torsional stiffness *P*. He then shows that the estimation of two bounds for *P* can be obtained with a simultaneous difference method. The method is applied to numerical estimation of *P* on both sides for the prismatic rod with quadratic cross section.

This method can be employed for the estimation of the torsional stiffness.

G. Sestini, Italy

52. **Cadambe, V., and Krishnan, S., Minimum weight design of thin-walled cells in torsion,** *J. roy. aero. Soc.* **59**, 530, 120–126, Feb. 1955.

The formulas derived in this paper can be used to compute the optimum sectional dimensions of a thin-walled circular, semicircular, rectangular, or triangular cell subjected to torsion on the basis of minimum weight. This does not take into account the possibility of there being other controlling factors on the sectional dimensions. However, even when there are such factors, the results can be usefully employed as a clue to the choice of the lightest sections, taking these factors into account. The curves have been found to yield results within 2% error. By selecting the nearest standard thickness on the higher side to the optimum value read from the figure, a safe design with high strength/weight ratio can be achieved.

From authors' summary

53. **Galletly, G. D., and Reynolds, T. E., A simple extension of Southwell's method for determining the elastic general instability pressure of ring-stiffened cylinders subject to external hydrostatic pressure,** *Proc. Soc. exp. Stress Anal.* **13**, 2, 141–152, 1956.

A variation is proposed of Southwell's method for using test data from a column with initial curvature to determine the buckling load of a perfectly straight column. Application is made to several models of ring-stiffened cylinders subjected to external hydrostatic pressure. Good correlation between theoretical and experimental buckling pressures is apparently obtained. A comparison of the experimental results is made with several theories. Kendrick's theory is in best accord with the method and experimental results.

J. Michalos, USA

54. **Argyris, J. H., Energy theorems and structural analysis, I.—General theory,** *Aircr. Engng.* **26**, 308, 347–356, Oct. 1954; **26**, 309, 383–387, 394, Nov. 1954; **27**, 312, 42–58, Feb. 1955; **27**, 313, 80–94, Mar. 1955; **27**, 314, 125–134, Apr. 1955; **27**, 315, 145–158, May 1955.

Expressions are derived for strain energy and complementary strain energy in three-dimensional state of stress and strain on assumption that stress-strain relationship is nonlinearly elastic and initial, particularly thermal, strains are present. The principles of virtual displacements and minimum strain energy and the theorems of Castigliano and Betti are proved and the Rayleigh-Ritz and Galerkin methods are presented. Upper and lower limits for structural stiffness are given. A principle of virtual forces or complementary virtual work is introduced as the dual of the principle of virtual displacements.

Flexibility and stiffness matrixes are discussed at length. They are used, by means of the generalized Mueller-Breslau technique, in calculation of stresses in structures with finite number of redundancies. Similarly, a generalization of Ostenfeld's displacement method is presented.

Paper is written for use by airplane structural analysts who will find useful the many, often numerical, applications to typical aircraft structures and the statement of the equations in matrix form suitable for automatic digital computation.

N. J. Hoff, USA

55. Argyris, J. H., and Kelsey, S., Energy theorems and structural analysis. II. Applications to thermal stress problems and St. Venant torsion, *Aircr. Engng.* **26,** 310, 410–422, Dec. 1954.

Methods developed in part I are used to solve four particular problems. The stresses are calculated rigorously in circular ring whose inner surface is unevenly heated both when stress-strain law is linear and when it is nonlinear. Thermal stresses are obtained approximately for rectangular plate. Upper and lower limits are given for torsional stiffness of thin sections and maximum stress is calculated approximately under torque; numerical values are presented for rectangular and double-wedge sections.

N. J. Hoff, USA

56. Dev Sharma, B., Stresses in an infinite slab due to a nucleus of thermoelastic strain in it, *ZAMM* **36,** 1/2, 75–78, Jan./Feb. 1956.

An infinite slab is at zero temperature while an infinitesimal element in it is kept at temperature T. At its lower surface the slab is fixed to a perfectly rigid base. Problem is treated as three-dimensional and no simplifying assumptions are introduced. Thermoelastic potential and Beltrami equations (equations of compatibility for the stresses) are used. Three stress systems are superposed. Improper integrals occurring in the solution are evaluated by replacing the integrand by an approximation function.

H. Parkus, Austria

57. Horvay, G., Thermal stresses in rectangular strips, *Proc. second U. S. nat. Congr. appl. Mech.*, June 1954; Amer. Soc. mech. Engrs., 1955, 313–322.

This paper aims at the generalized plane stress solution for an infinite strip ($-\infty < x < \infty$, $-1 \le y \le 1$), two halves of which ($-\infty \le x < 0$, $0 < x < \infty$) are maintained at uniform distinct temperatures, the boundary being free from tractions. The problem is reduced in the usual manner to an ordinary boundary-value problem characterized by a normal step loading. The latter problem is first treated by means of Filon's Fourier-integral solution for the general problem of the strip [*Phil. Trans. roy. Soc. Lond.* **201**, p. 63, 1903] through numerical evaluation of the improper integrals here involved. Next, the author applies a residue expansion to these integrals and arrives at a series solution in terms of Fadle's biharmonic eigenfunctions [*Ing. Arch.* **11**, p. 125, 1940]. Finally, the problem is attacked by means of an orthogonalized sequence of polynomials as Airy functions, each member of which meets the boundary conditions but fails to satisfy the compatibility condition (which is satisfied merely in the mean). This approach is due to the author [AMR **6**, Rev. 3018]. Numerical results are presented based on all three methods and the author concludes that the superiority of his own device has been "clearly established because of its speed and yet adequate reliability."

This reviewer is not in a hurry. He cannot help noting the discrepancies displayed in fig. 4 (at the singular cross section $x = 0$), which indicate that the author's scheme of approximation is not ideally suited to a problem whose very essence consists in the determination of a highly localized effect. He also feels that the singularities at $x = 0$, $y = \pm 1$, which are available in closed form, should have been removed.

E. Sternberg, USA

Experimental Stress Analysis

(See also Revs. 51, 53)

58. Mesmer, G., The interference screen method for isopachic patterns (moiré method), *Proc. Soc. exp. Stress Anal.* **13,** 2, 21–26, 1956.

Author describes an interference method for obtaining experimentally the pattern of lines of constant stress-sum in plane stress problems. This isopachic pattern may be combined with the isochromatic pattern obtained from a photoelastic test to determine the complete picture of the stress distribution.

Procedure consists in making a photograph of the interference pattern in a plane model without load due to the thickness variation in the model, and also a similar photograph after the model is loaded so that thickness variations due to the sum of the stresses affect the pattern. Superposition of these two photographs in negative form produce a mutual interference pattern (the moiré effect) which outlines the isopachic lines.

The method is an ingenious one, but seems to require many precautions and considerable experimental skill to get accurate results. It would appear that the well-known methods of graphical and numerical integration would be preferable if actual results were required.

W. O. Richmond, Canada

59. Johnson, R. C., Three-dimensional photoelastic analysis of shafts in pure torsion and a comparison with results from relaxation, *Proc. Soc. exp. Stress Anal.* **13,** 2, 107–118, 1956.

Problems treated are a prismatical bar of square cross section with a central circular hole, and an axially-symmetric bar of two diameters joined by a section with a depressed semicircular groove. Full details of the experimental procedure are outlined. Stress fixation was employed in the preparation of models, and oblique incidence retardation patterns were used to determine the shearing stresses at selected boundary points. The fringe order intensity (retardation/thickness) at the boundary was found by extrapolating intensity values out to the boundary from an interior point. Good agreement was obtained between the boundary stresses measured and those provided by relaxation procedures.

W. Shelson, Canada

60. Post, D., Photoelastic evaluation of individual principal stresses by large field absolute retardation measurements, *Proc. Soc. exp. Stress Anal.* **13,** 2, 119-132, 1956.

Experimental method of measuring absolute retardations at a point gives stress at that point without other measurements or analyses. Subsequent large field interferometric measurements provide principal stresses in two-dimensional models easily and rapidly. Tests on circular disk in compression show good correlation with theory. Photoelastic interferometer of the three mirror series design is found convenient to use. Favre, and Brahtz and Soehrens used similar but cumbersome techniques prior to 1940. Method is a step in the development of the one-model method for interior stresses in dynamic problems.

C. R. Freberg, USA

61. Gerard, G., and Gilbert, A. C., Note on photothermoelasticity, *J. aero. Sci.* **23,** 7, 702-703 (Readers' Forum), July 1956.

62. **Stein, P. K., Designing strain gage circuits for sensitivity and linearity,** *Prod. Engng.* **27,** 7, 144-149, July 1956.

63. **Kaufman, A. B., Accelerometer calibration by ballistic pendulum,** *Instrum. and Automat.* **59,** 7, 1322-1327, July 1956.

Of the six basic methods for accelerometer calibration, the ballistic pendulum provides vector (impact) test acceleration forces up to 500 g with the highest accuracy. Procedures, techniques, and variables are described for use of the ballistic pendulum, including details of calibration check and recording.

From author's summary

64. **Gustafson, G. V. A., and Olsson, C. O., An electronic apparatus for accurate measurement of periodic strains,** *Flygtekn. Försöksanst. Medd. Rep.* 63, 13 pp., 1956.

An electronic apparatus is described which will accurately measure the static value as well as the extreme values of a periodically varying phenomenon. It is especially adapted for measuring strains and loads in fatigue testing.

From authors' summary

Rods, Beams, Cables, Machine Elements

(See also Revs. 17, 30, 43, 44, 88, 90, 99, 115, 353)

65. **Poulsen, E., Continuous beams supported on linear elastic springs** (in Danish), *Bygnsstat. Medd.* **27,** 2, 77-102, June 1956.

It is shown how the application of matrixes gives a minimum of calculation: A force, moment, or deformation is found by the matrix equation

$$\bar{K} = \bar{K}_0 - \bar{\bar{K}}_1 \bar{\bar{\Delta}}_1^{-1} \bar{\Delta}_0$$

$\bar{K}_0$ and $\bar{\Delta}_0$ depend on the load, $\bar{\bar{K}}_1 \bar{\bar{\Delta}}_1^{-1}$ depend only on the construction and may be determined once and for all. Formulas are given for this product.

The method is illustrated by an example including determination of influence lines.

From author's summary by A. Selberg, Norway

66. **Williams, D., Relative accuracy of deflections and bending moments (or stresses) derived by the method of R.A.E. Report no. Structures 168,** *Aero. Res. Counc. Lond. curr. Pap.* 254, 11 pp., 1956.

Evaluation is given of errors in numerical method "RAE Rep No. Struct. 168" for deriving structural influence coefficients of aeroplane wings. Method is simple to apply and depends on representing transverse deflections by deflections at a number of stations. Bending and twisting moments at each station are determined in terms of the deflections at the small group of surrounding stations. Likewise, reactions at a station are determined in terms of moments at surrounding stations. Solution of the resulting simultaneous equations gives deflections in terms of the reactions. The report shows by examples of loaded beams and plates that in most practical cases the moments and deflections will be determined with about equal accuracy. The power of the method is seen in the fact that the solution for the bending moment at the center of a uniformly loaded clamped square plate is obtained within 5% using only 9 interior points on the plate.

S. Levy, USA

67. **Getz, J. R., Lovstad, C. D., and Moen, K., Beam knees. Strength and stiffness of lapped and butted beam knees welded to L-sections and to T-sections** (in Norwegian) *Norges Tekn.-Naturvitensk. Forskning. Skiptekn. Forskningsinst. Trondheim, Medd.* no. 8, 66 pp., 1955.

Models used are about in half scale; they form an L with equally long legs, and consist of frame, deck beam, and plating corresponding to one frame space. The static load is applied between ends of the legs by means of an hydraulic pressure cylinder. Deflections and strains are measured. Analysis of data is described thoroughly.

Presented results are: effective breadth of plating and of flanges, stress-concentration factors at knee toes and at upper edge of knee between frame and end of beam, average moment of inertia of beam including plating calculated from deflections, built-in point of beam, yield load or buckling load, ultimate load, and figures for stress in the free knee edge.

Stiffness of the very corner is not considered. It is obvious that stress concentrations at knee toes are very difficult to measure accurately due to very localized high stresses.

One connection was tested dynamically. A slowly propagating crack appeared in the beam at the knee toe.

Experimental data will be treated further in order to present results for design purposes.

E. Steneroth, Sweden

68. **Yasumi, N., and Okamura, H., Design diagrams for composite beams,** *Publ. Int. Assn. Bridge struct. Engng.* **15,** 267-275, 1955.

Following the necessity of easy and rapid determination of the most suitable and economical section of composite beams according to the design conditions, authors have composed convenient design diagrams. These diagrams can be used for determining the section of a composite beam in the case of composite action for both dead and live load.

From authors' summary

69. **Augustin, P., Variation of shear stresses in cross sections normal to the neutral axis of curved beams** (in Rumanian), *Acad. Repub. pop. Rom. Comun.* **6,** 1, 89-95, 1956.

Using the hypothesis which forms the basis of Jurawsky's law for the calculation of shear stresses in straight beams, author has established the law of variation of shear stresses in curved beams, for which Jurawsky's law represents the limit case. In this manner formulas have been derived for stressing of curved beams. In order to establish the degree of accuracy of this method, a particular case, that could also be treated using theory of elasticity, was investigated. It has been found that the errors arising from the use of the derived formulas are negligible from the engineering point of view. These formulas have the same degree of accuracy as the classical formulas used for the calculation of normal stresses in curved beams.

From author's summary by J. Solvey, Australia

70. **Trudsø, E., An electric model of beams and plates,** *Bygnsstat. Medd.* **26,** 1, 1-22, Aug. 1955.

An analogy is shown to exist between a simply supported horizontal beam loaded by vertical forces and a terminally-grounded electric conductor loaded at a sufficient number of points by currents proportional to the forces.

Moments correspond to potentials along the conductor, and the shear in a section is represented by the strength of the current through the corresponding section of the conductor. This conductor (I) thus approximates an electric analog of the beam.

The analogy also extends to the so-called "conjugate beam," the electric analog of which is a similarly grounded conductor (II) interconnected with conductor I through numerous high resistors linking corresponding points of I and II. Approximately, II is thereby loaded per unit length by currents proportional to the local potential of conductor I; and hence the currents and potentials thus caused in II depend in the same manner on the potentials of I as angular displacements and vertical deflections of a beam depend on its moments.

Through a feed-back procedure using electronic amplifiers, this analog may be extended to statically indeterminate beams, redundant forces (or moments) being simulated by servomechanically produced currents (or voltages) in I, which are subject to the constraint that certain deformation-representing voltages (or currents)

in II be nullified — in accordance with restraints against vertical deflections (or angular displacements) of the beam in question.

The analogy is applicable to plates, providing I and II are homogeneous sheet conductors of the same shape as the plate in question.

Various practical procedures of design of the analogs are discussed. A suggestion is made of a plate analog which does not utilize numerous resistors between corresponding points of I and II, but the sheet conductors are coupled in a purely capacitive manner. This plate analog displays as a characteristic feature that the two plane electric potential fields representing the distributions of moment and of deflection are *continuous* and are mutually coupled through a *continuous* medium.

Considerations of measuring technique enabling actual realization of such analogs is not discussed in the paper.

From author's summary by T. J. Higgins, USA.

Book—71. Shigley, J. E., Machine design, New York, McGraw-Hill Book Co., Inc., 1956, xiii + 523 pp. $7.75.

This book, written as a text for engineering students, stresses at each stage the factors to be considered and the decisions to be made in mechanical design, including strength, functioning of parts choice of material, method of manufacture, cost,etc. Part I is main concerned with materials to be used, the first 177 pages giving a survey of stresses, deflections, mechanical properties, criteria of failure, manufacturing processes (including the elements of metallurgy), and ending with principles of design. In part II the design of selected machine elements is considered. These comprise: screws, fasteners and joints; springs; antifriction bearings; journal bearings; spur gears; helical, worm, and bevel gears; clutches, brakes, and couplings; flexible elements. A final chapter is devoted to miscellaneous elements including cylinders, flat plates, and rotating disks. Examples of design calculations are frequently given, while a bibliography and a list of problems are appended to most chapters.

Presentation of the subject is clear and a vast amount of useful information (together with instructions for its use) is gathered together from a variety of sources. The choice of subjects in part II, however, is somewhat arbitrary and, in the reviewer's opinion, a little unbalanced. While 66 pages are devoted to bearings and 89 to gears, little information is included on the design of many common machine components such as, for example, a simple crankshaft.

R. N. Arnold, Scotland

72. Hall, K. W., and Alvord, H. H., Load-carrying capacity of spur-gear teeth hob cut from molded du Pont "Zytel" 101, ASME Semiann. Meet., Cleveland, O., June 1956. Pap. 56–SA–43, 8 pp.

Paper presents a method of calculating the load-carrying capacity of spur-gear teeth hob cut from molded du Pont "Zytel" 101, both with and without lubrication. The method is based on results obtained by testing seventy-two gears in five "back-to-back" test machines. Breaking strength rather than tooth wear governs the load-carrying capacity of these teeth. However, wear rates of the teeth, with and without lubrication, are presented also.

From authors' summary

Plates, Disks, Shells, Membranes

(See also Revs. 30, 31, 33, 34, 53, 57, 66, 91, 92, 93, 94, 95, 96, 99)

73. Granholm, H., Boussinesq's problem, an approximate method for calculation (in Swedish), *Bygnsstat. Medd.* **27,** 2, 63-75, June 1956.

Author presents a simplified derivation of stress and deformation in a half space subjected to concentrated normal force. Dividing half space in conical shells with their apex at point of concentrated force, an approximate solution is found which neglects dilatation effects. It is shown that solution coincides with Boussinesq's results when Poisson's ratio = 0.5, and represents a good approximation in other cases. Analysis is extended to inhomogeneous media composed of two layers with different moduli of elasticity. In latter case, degree of approximation is more difficult to estimate.

S. Sjostrom, Sweden

74. Szelagowski, F., The influence of a bolt inserted in a hole of an infinite plate subjected to one-directional tension or compression on the stresses in the plate, *Bull. Acad. Polonaise Sci. Cl. IV* **4,** 1, 9-20, 1956.

Author derives equations giving stresses in an infinite plate subject to one-dimensional tension or compression and having a bolt, either rigid or elastic, in a hole in the plate. No load is applied to the bolt by external forces. Solution is obtained by superposition of the stresses in an infinite plate with a circular hole and one-dimensional stresses, and the stresses in an infinite plate with a hole loaded by radial stresses along the periphery of the hole. Author shows that the radial stresses occur only on sections of the periphery and that the sections are determined by the elastic constants of the material in the plate and bolt. Angles indicating the stressed portions of the periphery are determined for a steel plate with either a rigid or steel bolt. Symbols used are not well defined.

W. B. Stiles, USA

75. McKenzie, K. I., and Rothman, M., Note on the bending of a finite parallelogrammic plate under continuous non-loading, *J. roy. aero. Soc.* **60,** 542, 134-136 (Technical Notes), Feb. 1956.

76. Cadambe, F., Kaul, R. K., and Tewari, S. G., Flexure of thin elastic plates under specified edge tractions, *Indian J. Phys.* **29,** 9, 403-416, Sept. 1955.

For solving the problems of flexure of thin elastic plates under specified edge tractions, two second-order differential equations, which were previously obtained by Southwell, are deduced by variational principles. These equations involve two expressions U and V which represent bending and twisting moments, respectively.

Methods of solving two examples, namely, that of a square plate acted upon by bending couples distributed uniformly along the edges and of bending of a cantilever plate under uniformly distributed load, are explained.

S. C. Das, India

77. Matildi, P., Solution of a rectangular clamped plate (in Italian), *Atti Acad. Sci. Torino* **89,** 3-20, 1954-55.

The solution is developed in terms of convergent series,employing elementary functions used in beam theory. A criterion for evaluation of the error involved in each step of the analysis is presented.

G. Herrmann, USA

78. Doman, J. P., and Schwartz, E. B., Study of size effect in sheet-stringer panels, *NACA TN* 3756, 8 pp. + 3 tables + 14 figs. July 1956.

The object of this study was to determine whether there are significant size effects in compressive strength of large Z-stiffened sheet-stringer panels as compared with geometrically similar smaller models, and thus to ascertain whether the prediction of the strength of large panels by model tests is reliable.

The specimens for the study were manufactured from 7075-T6 aluminum alloy. There were four representative types of panel designs, with full-scale and one-quarter-scale panels of each type.

A comparison of the average failing stresses shows that there is no significant effect due to the panel size.

For the panels tested, which failed by general instability, there was no significant compressive-strength size effect between the large Z-stiffened prototype and geometrically similar model panels.

From authors' summary

79. Salvadori, M. G., Analysis and testing of translational shells, *J. Amer. Concr. Inst.* **27,** 10, 1099-1114, June 1956.

The general theory of thin translational shells was developed by Pücher and Flügge. In present paper, the finite difference approach of Pücher is applied to analysis of translational shells generated by arcs of circles. Formulas are obtained for analysis of rectangular shells and applied numerically to a square shell. Tests to destruction were conducted in Piacenza, Italy on a 30 x 45-ft shell of this type. Tests of this reinforced-concrete and tile shell proved the complete validity of assumptions and results of analysis.

From author's summary by R. B. McCalley, Jr., USA

80. Layrangues, M., Elastic deformation of thin shells (in French), *Ann. Ponts. Chauss.* **126,** 1, 39-76, Jan./Feb. 1956.

The elastic deformation of thin shells is treated by vectorial methods, but without using the general differential calculus. The equations are applied to the case of the cylindrical shell.

H. Neuber, Germany

81. Sokolov, A. M., Applicability range of the momentless theory to calculations of shells with negative curvature (in Russian), *Izv. Akad. Nauk SSSR Otd. tekh. Nauk* no. 5, 85-101, May 1955.

One-sheeted hyperboloidal shell of revolution is considered as subject for analysis. This type of shell is practical and is relatively easy to handle mathematically. The two edges are assumed closed and lie in planes that are perpendicular to the axis of the shell. The shell has negative curvature.

Attention is focused on clarification of conditions of applicability of membrane theory of Novodvorsky which demands that edge restraints be such as to eliminate possibility of bending of the middle surface. Goldenweiser showed that, for nonbending of middle surface satisfying Novodvorsky's conditions, it is necessary to use one kind of tangential restraints, which is the type of restraints considered in his article.

The case when edges are restrained only in one of the two tangential directions remains not clear and clarification of this problem is the subject of present paper.

S. Sergev, USA

82. Vlasov, V. Z., Theory of momentless shells of revolution (in Russian), *Izv. Akad. Nauk SSSR Otd. tekh. Nauk* no. 5, 55-84, May 1955.

Author defines momentless shell (membrane) as a thin-walled space structure formed about a given surface in an unloaded state and at no point exhibiting resistance to deformation of bending. Considering shells of revolution, author writes three equilibrium equations in terms of normal and tangential components of external loading and the three components of the tensor of stressed state of the shell, followed by three equations of extensional deformation of the middle surface in terms of the displacements.

Assuming surface loading and extensional deformations to be zero results in three homogeneous equations of equilibrium and three homogeneous equations in the displacements. Using static-geometrical analogy, three more equations are written from equilibrium equations in terms of components of deformation of bending.

Utilizing stress, displacement, and deformation functions, the three systems of equations are described by two unifying functions. Further, by proper substitution, one determining equation of second order is written in which the unknown function can be the stress, displacement, or deformation function of the inextensional shell.

The remainder of the work is devoted to discussion of particular shells, with positive and negative curvatures, as well as composite shells. Deformation of bending is considered infinitely small.

S. Sergev, USA

83. Nash, W. A., and Hijab, W., Stresses in non-uniformly supported cylindrical tanks, *Publ. Int. Assn. Bridge struct. Engng.* **15**, 153-166, 1955.

"An equilibrium analysis is presented for the problem of a vertical cylindrical tank subject to an axial loading distributed uniformly around the circumference of the shell at its upper extremity and supported nonuniformly by the foundation at its lower extremity. Infinite series expressions, compatible with boundary conditions, are assumed for the three orthogonal displacement components, and the principle of minimum potential energy is employed to determine the various coefficients of the series. From these displacements, the normal and shearing stresses in the shell may be determined to any desired degree of accuracy by the usual stress-displacement relations for thin shells."

Reviewer believes the assumed boundary conditions on the displacements may be unrealistic for short cylinders, particularly the assumption that the tangential displacement at the upper and lower ends is zero. This latter assumption prevents the wall of the tank from acting as a beam across the unsupported section. For the numerical example in the paper, the center deflection of the wall as a fixed end beam across the unsupported section is about thirty times that obtained in the paper (the length of the unsupported section is nearly four times the height of the wall).

B. E. Gatewood, USA

84. Wagner, H., A simplified stress calculation of noncircular tubes under internal pressure (in German), *ZVDI* **98**, 20, 1053-1054, July 1956.

Several known solutions for elliptical tubes under internal pressure are reviewed, and a simple expression is derived for the stress coefficients relating the maximum and minimum bending moments to the customary nondimensional parameter qa^2/s^2 , where q is the internal pressure, a the semimajor axis, and s the wall thickness.

C. C. Wan, USA

85. Rodabaugh, E. C., and George, H. H., Effect of internal pressure on the flexibility and stress intensification factors of curved pipe or welding elbows, ASME Semiannual Meet., Cleveland, O., June 1956. Pap. 56-SA-50, 23 pp.

The flexibility and stress-intensification factors presently applied in piping flexibility analysis to account for the behavior of curved pipe in bending have been derived from theories and tests with no internal pressure. Pressure tends to reduce the effect of these factors, but in smaller and relatively thick-wall piping, commonly used in the past, the effect is of a low order and may be neglected; in larger diameter, relatively thin-wall piping, the effect is pronounced and significant.

Using strain-energy methods, present paper develops a theory establishing the flexibility and stresses due to in-plane and out-of-plane bending, including the effect of internal pressure, and proves its adequacy by means of carefully conducted tests. In a final step, the complex theoretical formulas are reduced to a simple and readily usable approximation.

From authors' summary by J. L. Lubkin, USA

86. Galletly, G. D., Analysis of discontinuity stresses adjacent to a central circular opening in a hemispherical shell, *David W. Taylor Mod. Basin Rep.* 870 (Rev.), 30 pp., May 1956.

Buckling Problems

(See also Rev. 53)

87. Howell, G. H., Column formulas—four basic types, *Proa. Engng.* **27,** 4, 139-141, Apr. 1956.

88. Falk, S., Buckling formulas for a bar composed of n parts of constant bending stiffness (in German), *Ing.-Arch.* **24,** 2, 85-91, 1956.

Author presents exact solution of buckling condition for system mentioned in title by application of matrix calculus. He derives the main matrix for the single case of buckling, considering arbitrary end conditions and derives from it the buckling determinant, when this bar consists of many different sections. Simplifying this determinant, author obtains a very useful explicit representation of the buckling condition, which permits direct evaluation of lower limit of critical load.

Amplication of buckling determinant, including bars with intermedial elastic supports, is possible, too. Two examples are given.

Reviewer believes that exact solution presented by author is very appropriate to check approximative methods, but is too laborious for practical calculation. H. Beer, Austria

89. Dutheil, J., On the stability of compression members in the elastoplastic region (in French), *Ann. Inst. tech. Bât. Trav. publics* **9**, 102, 483–510. June 1956.

Author establishes a graphical representation for equilibrium of elastoplastic light alloy columns, with particular reference to Shanley's theory. He concludes that, for a real (strain-hardening) material, the tangent modulus concept is not valid.

J. Heyman, England

90. Pettersson, O., Some stability and second-order stress problems of beams, frames, arches, and plates (in Swedish), *Instn. Hållfastbetslära, KTH, Publ.* 113, iv + 113 pp. + 37 diagrams, 1955.

The publication is written in the form of notes for a series of lectures on strength of materials given by the author during the 1955 autumn term at the Royal Institute of Technology, Stockholm. It is divided into six chapters: (1) Survey of methods for the determination of the stability condition of elastic systems; (2) Buckling of beams under combined axial and transversal load; (3) Buckling of frames under combined axial and transversal load; (4) Buckling of arches, additional bending moments of arches; (5) Buckling of plates under combined lateral load and load in the plane of the plate; (6) Combined bending and torsion.

Author presents his subject in a clear and straightforward way and gives a number of instructive examples, where, however, cumbersome calculations often are left out. A valuable bibliography lists 52 papers and books on the subject, which author has used in preparing the text. A summary in English is given at the end. Publication seems to be well suited as basis for a course on the subject and may also be a valuable guide for the practical engineer. L. N. Persen, Norway

91. Thielemann, W., Buckling of anisotropic plate strips (in German), *Dtsch. Versuchsanstalt Luftfahrt E. V., Rep.* 16, 70 pp., June 1956.

Orthotropic plates occur in engineering applications such as stiffened plates, plywood, corrugated sheet, and laminated glass cloth. Nonorthogonally anisotropic plates also exist in, for example, aircraft delta wings and in some laminated woods and fabrics. This paper presents an exact buckling theory for such plates, using classical elastic assumptions and energy methods. Plates with simply supported edges and clamped edges are examined under both shear and uniaxial compression loadings. It is found that, in each case, the buckling load can be expressed as a function of only two elastic constants. The results are presented in the form of curves from which the buckling load can be immediately found, given the plate dimensions and elastic constants. Curves showing the effect on buckling strength of varying the angle of inclination of stiffeners are also included.

In addition, there is an interesting investigation of the possible range of values of orthotropic elastic constants which makes the paper of importance to those concerned primarily with tensile behavior as well as those concerned with the subject problem. In isotropic materials, for instance, Poisson's ratio must fall between the limits + 1 and − 1 in two-dimensional problems (between + 1 and − 0.5 in three dimensions). A. D. Topping, USA

92. Brcic, V., On the stiffening of a rectangular plate loaded with a shear force (in German), *Stahlbau* **25**, 4, 88–90, Apr. 1956.

The instability of a simply-supported rectangular plate with equally spaced cross stiffeners under uniform shearing load is investigated. A system of linear homogeneous algebraic equations has been established by using double Fourier series expansion. The determinant of such system of equations gives the solution for critical shearing load if a plate together with its stiffeners is specified. Moreover, the value of minimum stiffness, required for each rib in order to sustain a maximum possible shearing load of a given plate with specified number of stiffeners, can also be computed from this determinant. Examples for both types of problems are cited by taking a finite truncated series, and numerical values for a few simple cases are tabulated and plotted in curves. A comparison is made with some results obtained earlier by Timoshenko by means of energy method. The curves indicate that, for a plate with given number of ribs, the minimum value of stiffness required for each rib diminishes rapidly as the shape ratio increases.

T.-T. Loo, USA

93. Horne, M. R., The progressive buckling of plates subjected to cycles of longitudinal strain, *Trans. Instn. nav. Arch. Lond.* **98**, 1, 78–107, Jan. 1956.

Problem may be considered as a nonconvergent shakedown process in which the members supporting the plates undergo no permanent deformation. This problem arises in bottom plates of ships which have transverse framing. Charts are given showing the conditions under which large plate deformations may be developed by shake-down, and the stresses allowable in the supporting members if such large deflections are to be avoided. Two general cases are considered, first a single panel, then a series of panels without substantial cross members. The effect of lateral plate pressures is not considered, but the discussion points out that this is a minor omission. The usual ideal plastic material assumptions are made. There are elaborate charts and excellent graphs for design purposes. It is concluded that the single plate problem is of academic interest only, but the series of panels may develop large deflections in practical cases, with the panel having the largest initial deflection being the worst case.

Reviewer considers paper an excellent example of analytical approach and a careful presentation of valuable information.

T. A. Hunter, USA

94. Clark, J. W., Buckling efficiencies of plate materials at elevated temperatures, *J. aero. Sci.* **22**, 9, 659–660 (Readers' Forum), Sept. 1955.

Author points out that considering compressive yield stress as a structural efficiency parameter can lead to erroneous conclusions. If two plates made of different materials are under the same load and the thickness of each plate is adjusted to take account of the differences in density, then, if they buckle at the same load, this load may coincide with the compressive yield stress of one but not the other.

It is advanced that there may be no single parameter which will adequately rate materials for their relative resistance to buckling in the plastic range. A. D. Schwope, USA

95. Przemieniecki, J. S., Buckling of rectangular plates under bi-axial compression, *J. roy. aero. Soc.* **59**, 536, 566–568 (Technical Notes), Aug. 1955.

Critical values of stress parallel to sides is plotted versus side-to-end ratio with stress parallel to ends as parameter for simply supported ends and sides either simply supported or fixed.

M. G. Salvadori, USA

96. **Bogunovic, V., Stability of reinforced plates** (in German), *Stahlbau* **24**, 1, 8–11, Jan. 1955.

Author studies the critical load that may be carried by a simply supported T-beam belonging to a set of such beams carrying loads that act on the ribs, producing bending. In such a case, for very thin plates, there is a danger of buckling.

First, the state of stresses of the T-beam is analyzed, through an Airy-function ϕ_1 for the rib, and another one ϕ for the plate, which gives the stresses σ_x, σ_y, τ. Then these values are substituted in the well-known differential equation of the plate [Timoshenko, "Elastic stability," p. 305], using a double trigonometric series for the deflection surface. Thus an equation is obtained that allows finding the coefficients of the series belonging to a system of linear and homogeneous equations, whose determinant must be null in order to obtain the value of the critical load.

In a final table, author gives the results of his analysis for several relations between width of the rib/thickness of plate, indicating when either the buckling of the plate or the resistance of the rib is decisive. A. M. Guzman, Argentina

97. **Blaise, P., Buckling of joined arches** (in French), *Ann. Ponts Chauss.* **126**, 1, 1–38, Jan./Feb. 1956.

With reference to two former papers "Formules élémentaires pour le calcul des poutres, arcs et portiques à plan moyen" [AMR **6**, Rev. 829] and "Les déformations dans les poutres et arcs à plan moyen" [title source, 1954], author treats the buckling problem of clamped arches with (at most three) hinges. Numerical data are provided for three special cases.

Reviewer comments that, in the interest of the author who wishes to be read as well as for the reader who may rightly expect all possible help from the author, a paper should be readable in itself, and that clarifying illustrations should not *altogether* be omitted.

C. B. Biezeno, Holland

98. **Voinea, R., Contributions to the study of the elastic stability of statically indeterminate structures** (in French), *Acad. Repub. pop. Rom. Rev. Mecan. appl.* **1**, 1, 185–202, 1956.

The stability of a rigid slab supported by elastic columns partially built in at both ends is examined. Failure is shown to take place either by a rotation of the slab about an axis perpendicular to the slab or by a simple translation. Expressions are derived to locate the instantaneous axis of rotation. Two numerical examples are given. One of these examples shows that the factor of safety of the slab and its columns is greater than the minimum factor of safety of the individual columns.

N. C. Costakos, USA

99. **Peterson, J. P., Bending tests of ring-stiffened circular cylinders,** *NACA TN* 3735, 14 pp., July 1956.

Twenty-five ring-stiffened circular cylinders were loaded to failure in bending. Results are presented in the form of design curves which are applicable to cylinders with heavy rings that fail as a result of local buckling. From author's summary

100. **Gerard, G., Torsional instability of hinged flanges stiffened by lips and bulbs,** *NACA TN* 3757, 12 pp., Aug. 1956.

Based on torsional instability theory, buckling charts are presented for determining the critical strain of hinged flanges stiffened by idealized lip and bulb elements.

From author's summary

Joints and Joining Methods

(See Rev. 120)

Structures

(See also Revs. 48, 52, 54, 55, 65, 67, 78, 79, 83, 90, 97, 98, 328, 330, 352)

101. **Ettore, F., Application of Colonnetti method to the structural analysis of an arch-frame combination** (in Italian), *G. Gen. civ.* **94**, 4, 207–227, Apr. 1956.

Author gives analytical version of a graphical method ascribed to Colonnetti. A redundant structure, composed of an arch and a horizontal beam, which are connected by vertical links, is analyzed in classical manner. The deformations of the different substructures are obtained separately and used to establish equations for the redundant forces in the vertical links. The deformations of the arch are analyzed by the use of elastic weights and the ellipse of elasticity. B. Langefors, Sweden

102. **Minnich, H., Generalization of Nokkentved's method** (in German), *Bautechnik* **32**, 11, 364–367, Nov. 1955.

Author treats the following problem: A rigid body subjected to known loads is supported at various points by ties and struts with different inclinations. The forces in the supports are to be found. In this analysis it is assumed (a) that all forces are in a plane (or disposed symmetrically in parallel planes) and (b) that ties and struts are pinned at ends. This method is recommended where the degree of redundancy is more than two. In effect, the method consists in assuming two unknown perpendicular components of displacement and a rotation of the body. The resulting reactions from the supports (two generally normal forces and a moment about their point of intersection) are equated to the components of the loads and the moment of the loads about the same point. The analysis is presented in the form of a cookbook solution of a set of equations.

M. P. White, USA

103. **Asplund, S. O., Matrix-analysis of successive moment-distribution,** *Publ. int. Assn. Bridge struct. Engng.* **15**, 17–29, 1955.

The procedure of successive moment-distribution is interpreted by an infinite matrix series whose definite sum is also given. It is shown that this sum coincides with the corresponding finite expression deduced without approximations by the classical theory of elastic structures. It is finally demonstrated that the matrix series for moment-distribution in stages (as defined) is asymptotic to geometric series whose common ratio and various sums can be approximated. The matrix method given is exemplified on an ordinary frame problem and on a frame-buckling problem.

From author's summary by F. W. Niedenfuhr, USA

104. **Prager, W., The general theory of limit design,** *Proc. eighth int. Congr. theor. appl. Mech.* 65–72, 1955.

Author notes the need for establishing basic theorems of limit design for plates and shells. For such bodies, these are simpler to apply than those devised for three-dimensional continuum. These theorems are discussed and their application to two particular cases is illustrated. E. P. Popov, USA

105. **Rawlings, B., The analysis of partially plastic redundant steel frames,** *Austral. J. appl. Sci.* **7**, 1, 10–22, Mar. 1956.

A method is outlined whereby the moment distribution in a redundant steel frame can be determined throughout the elastoplastic range. Flexural deformation only is considered. The frame is treated as a series of elements, each consisting of a beam subjected to end moments only, and the relationships between slopes and deflections of members are established by means of compatibility equations. A fixed base rectangular portal frame is taken as an example, and it is shown that the solution can be facilitated by the use of a matrix. From author's summary

106. Ferguson, P. M., Simplification of design by ultimate strength procedures, *Proc. Amer. Soc. civ. Engrs.* **62,** ST 4 (*J. Struct. Div.*), Pap. 1022, 25 pp., July 1956.

Based on the 1956 "Report of ASCE-ACI Joint Committee on Ultimate Strength Design" and upon the use of a rectangular stress block, design procedures for beams and columns are developed. Although the use of design charts is recommended, it is shown that most calculations are simple and practical without such aids. Design procedures are, moreover, simpler than present working stress methods. The Appendix contains some numerical examples.

From author's summary

107. Erzen, C. Z., Analysis of suspension bridges by the minimum energy principle, *Publ. int. Assn. Bridge struct. Engng.* **15,** 51–68, 1955.

Author uses the principle of minimum potential energy in deriving two equations for the analysis of suspension bridges. Horizontal as well as vertical displacements of the cable are considered. One of these equations reduces to the well-known fourth-order differential equation of a suspension bridge, and it is this latter familiar form that is used by the author. The other equation leads to the trivial static condition that the final resultant horizontal tension in the cable must be a constant, and the second equation used by the author is actually obtained by considering the strain in the cable. The approach therefore turns out to be essentially the same as that indicated by Karman and Biot ["Mathematical methods in engineering," pp. 277–283]. The strain expression for the cable is rather involved due to the inclusion of the horizontal displacement, and it leads to rather cumbersome expressions for the determination of the additional cable tension.

Numerical example shows that the value of this additional tension determined by using author's results is within 10% of those determined by Johnson, Bryan, and Turnearne ["Modern framed structures," John Wiley & Sons, Inc., 10th ed, 1929, part II, pp. 271 ff] and by Timoshenko ["The stiffness of suspension bridges," *Trans. Amer. Soc. civ. Engrs.* **94**, p. 391, 1930].

The value of considering the horizontal displacement of the cable is questionable, for the assumption of equal vertical displacement for the cable and the truss implies that the horizontal displacement may be neglected.

Y-Y. Yu, USA

108. Hoyden, A., Approximate calculation of ground-anchored suspension bridges with stiffening girders of variable moment of inertia (in German), *VDI-Forschungsheft* (B) **21,** 452, 39 pp., 1955.

Suspension bridges with stiffening girders or trusses of variable moment of inertia have been previously analyzed [Hans H. Bleich, F. Stüssi, S. Timoshenko] and the variable section was found to affect but slightly the resulting bending moments. Bending moments are still smaller when the second-order analysis is used, i.e., considering large deformations. Author presents method of calculation for such bridges, based on second-order theory, in two main sections referring to constant and variable moment of inertia of the stiffening girders or trusses. The first more simple method is recommended for preliminary design of the supporting cables and the stiffening girders; to be followed more accurately by design considering variable moment of inertia. Both calculations are based on energy equations and carried out with series which, in the second method, are solved by iteration with greater accuracy.

The methods are applied to a numerical example (suspension bridge spanning 420 – 1130 – 420 ft with constant and variable moments of inertia of the stiffening girders. Author's conclusions are: (1) Design of relatively slender stiffening girders (when dead load is carried only by cables) depends only on radius of the deflection line whereby the radius of curvature is practically independent of variation of moment of inertia. (2) Smallest radii of curvature of deflection line calculated for constant moment of inertia are accurate enough for determination of the resulting bending moments which can be adjusted for variable moments of inertia in simple way. References are made to J. Melan, K. Kloeppel, K. H. Lie, F. Stuessi, J. Fritsche, S. O. Asplund, Fr. Dischinger, A. Selberg, O. F. Theimer, P. Savoly, and others.

J. J. Polivka, USA

109. Bisplinghoff, R. L., Some structural and aeroelastic considerations of high-speed flight, *J. aero. Sci.* **23,** 4, 289–329, 367, Apr. 1956.

In this Nineteenth Wright Brothers Lecture, problems caused by supersonic speeds in structures of manned aircraft of foreseeable future are discussed. Design trends since 1920 are reviewed. Principles and formulas are given for heat transfer to structure from environment, and temperature distribution in structure is analyzed. Effect of gusts upon elastic airplane is treated. Thermal stresses and reduction in vibrational frequency are calculated, and effect of high temperatures on static and dynamic aeroelastic phenomena is investigated. Creep and fatigue are mentioned only briefly. Design measures to alleviate undesirable effects of aerodynamic heating are proposed. Analytical results are compared with experimental data whenever available, and problems of structural testing are discussed at some length.

Paper summarizes work carried out on subject at MIT and elsewhere.

N. J. Hoff, USA

Rheology (Plastic, Viscoplastic Flow)

(See also Revs. 43, 44, 89, 93, 94, 105, 110, 123, 124, 126, 143, 145, 146, 147)

110. Weertman, J., Creep of polycrystalline aluminium as determined from strain rate tests, *J. Mech. Phys. Solids* **4,** 4, 230–234, Aug. 1956.

Constant strain-rate tests were conducted on high-purity polycrystalline aluminum at various temperatures. Under low loads, a steady-state period was reached during which stress remained constant. Relationship between stress and strain rate is shown to agree with corresponding data from constant stress-creep tests. Relationship also agrees with data for single crystals.

L. Mordfin, USA

111. Marin, J., and Griffith, J. E., Creep relaxation of Plexiglas IIA simple stresses, *Proc. Amer. Soc. civ. Engrs.* **82,** EM 3 (*J. Engng. Mech. Div.*), Pap. 1029, 20 pp., July 1956.

A relation well representing creep data is made of four strains, namely, elastic, plastic, transient creep, and steady-state creep, each of which can be expressed as a function of stress, time, *e*, and certain experimental constants. The methods for determining the latter are given for compressional, tensile, and bending stresses. These constants are given in tables. Curves obtained by plotting measurements data approximately agreed with the curves derived from the proposed equation. The accuracy of the creep-stress-time equation proposed for predicting creep relaxation for tension and compression was checked experimentally, and a graphic solution of the equation presenting this relation is offered. It points to a good agreement between the theoretically predicted and actual behavior.

J. D. Gat, USA

112. Troost, A., Strength calculations for mixed elastic-plastic deformations (in German), *Z. Flugwiss.* **4,** 3/4, 122–128, Mar./Apr. 1956.

Author develops empirical formula for expressing stress-strain relationship in plastic flow of metals, for small plastic strains of the order of 3–1/2 times Hookean strain limit. Virtue of this treatment lies in requirement of only two constants, determined experimentally by simple tension tests: Youngs' modulus (at elastic strain limit) and a parameter K, labelled "plasticity factor." K varies between zero (ideal elasticity) and unity (ideal elastic-plasticity); it is a nonlinear function of the elastic stress (strain) limit but is relatively insensitive to elastic modulus over 3-fold range of the same.

It is shown possible to predict maximum (tension) bending stress from measurement of tensile stress for 0.2% permanent deformation and the elastic modulus, in beams of rectangular and circular cross section. Similar empirical considerations illustrate application to beams of I, cruciform, and polygonal cross section. Although only condition of 0.2% permanent deformation is developed, it is claimed similar treatment will be valid to establish plastic bending stress limits from tensile data for other permanent-strain criteria, within the elastic-plastic domain. Application to alternating-stress problems and notched, flat bars in tension is likewise described.

This paper should be of interest to structural designers; it is empirical, however, and does not treat theory of plasticity nor aspects of analytical limit design. J. T. Bergen, USA

113. De Pando, M. V., A minimum principle for the elastic-plastic state (in Spanish), *Rev. Cienc. apli.* **10**, 49, 97–100, Mar./Apr. 1956.

114. Haythornthwaite, R. M., and Onat, E. T., The load carrying capacity of initially flat circular steel plates under reversed loading, *J. aero. Sci.* **22**, 12, 867–869, Dec. 1955.

The testing of a simply supported, centrally loaded mild-steel plate, 20-in. diam, is described. The plate was loaded well into the plastic range and then reloaded in the reverse sense. Under reversed loading, temporary plastic instability was observed, as predicted by applying a new large-deflection theory for plates composed of rigid plastic material. Earlier tests have shown that the limit load obtained by neglecting changes in geometry is often of little physical significance for a monotonically increasing load. These tests show that, in reversed loading, it becomes a measure of the minimum load-carrying capacity available during a phase of plastic instability. From authors' summary

115. Raevskaia, E. A., Calculation of cantilevered I beams under restrained torsion beyond the elastic limit by the method of limit equilibrium (in Russian), *Inzhener. Sbornik, Akad. Nauk SSSR* no. 20, 93–100, 1954.

Based on an idealized plastic stress distribution, a method is presented for obtaining upper and lower limits on the ultimate twisting moment which a beam of given length can sustain. The torsional resistance is divided into that due to twist and that due to flange bending. The Nadai sand-heap analogy is employed. A refined calculation is made to show that transverse shear stresses in the web, where web and flange meet, have negligible influence on the plastic flow condition in the flanges. The theoretical results are compared with experimental data obtained by another investigator. B. Wilson, USA

116. Bishop, J. F. W., Green, A. P., and Hill, R., A note on the deformable region in a rigid-plastic body, *J. Mech. Phys. Solids* **4**, 4, 256–258, Aug. 1956.

It is established that the deformable region in a rigid-plastic body yielding under given boundary conditions can be determined from an examination of one complete solution. Particular methods are suggested for determining this region, and are illustrated by a consideration of indentation under conditions of plane strain, plane stress, and axial symmetry. From authors' summary

117. Love, E. R., Linear superposition in visco-elasticity and theories of delayed effects, *Austr. J. Phys.* **9**, 1, 1–12, Mar. 1956.

Author shows that, when linear superposition is observed in after-working phenomena, the Boltzmann memory-relation between stress and strain history does not necessarily follow. He establishes three additional conditions which are necessary and sufficient. M. Reiner, Israel

Failure, Mechanics of Solid State

(See also Revs. 50, 89, 112, 126, 315, 345)

Book–118. Odqvist, F. K. G., and Weibull, W., (editors), Colloquium on fatigue, Berlin, Springer Verlag, 1956, xi + 339 pp. DM 46.50.

Fatigue in metals has, until recent years, been a very specialized engineering topic. Within the last 18 months, however, three international conferences on fatigue have been attended by a large number of mathematicians, physicists, and metallurgists. At the first of these meetings, the IUTAM Colloquium on Fatigue, held in Stockholm, May 1955, 35 papers were presented dealing mainly with basic problems.

The largest group (12 papers) concerns the mechanism of fatigue. The main topics are structural changes prior to the occurrence of fatigue cracks (M. Hempel; R. Jacquesson; I. A. Oding; F. R. Shanley; R. J. Taylor; F. Wever); use of second-order terms in strain components in elasticity equations (A. Kammerer); size effect and notches (P. Kuhn; G. V. Uzhik); influence of chemical reactions at the metal surface (O. Lissner; C. Schaub and W. Liedtke); and the relations between torsion and tension fatigue on the basis of slip mechanisms (R. E. Peterson). Although no unique and clear picture of the fatigue mechanism can be obtained from these studies, the early onset of microscopic damage along slip lines and slip bands, later forming the fatigue crack, is now well established.

Another field that has recently attracted much attention, especially in aircraft and automobile design, is the effect of cumulative damage. Miner's simple hypothesis [*J. appl. Mech.* **12**, A 159–A 164, 1945] is not supported by recent experimental results (L. Locati; F. J. Plantema; E. W. C. Wilkins). Some presented physical and statistical aspects (A. M. Freudenthal; E. Gassner) are of a more general nature.

The statistical approach to fatigue has proven very fruitful and, for example, the concept of *P–S–N*-curves is widely used throughout the papers. Statistical planning of tests is discussed (F. Bastenaire; F. Bastenaire, R. Cazaud and M. Weisz; J. T. Ransom), as well as statistical analysis of fatigue test data (F. Gatto). Influence of different variables such as heat treatment, machining history, and surface finish on the variability in testing is studied (F. A. McClintock). Though the importance of differing between crack formation and crack growth is stressed (W. Weibull), only two papers deal with crack propagation (C. E. Phillips; P. E. Wiene).

Experimental results from the outskirts of the classical fatigue domain are reported, such as fatigue at elevated temperature (A. Fransson; A. Johansson) and fatigue at high loads (R. B. Heywood; J. Salokangas). The Prot method of fatigue testing [AMR **1**, Rev. 111] is duscussed in several papers (e.g.,A. Ferro and U. Rossetti), influence of combined stresses in only one (W. N. Findley), as well as the special topic of contact fatigue (A. I. Petrussewitsch). Finally, reviews of the fatigue work done at some research centers are given (P. Laurent; L. Martinaglia; D. G. Sopwith).

The book contains the full papers except for one case (E. Gassner) and the discussions are also included, but are generally of smaller interest. The book appeared less than one year after the Colloquium. The editors and the secretary are to be credited for this promptness, invaluable in a rapidly developing field of science. J. Hult, USA

119. Raring, R. H., and Rinebolt, J. A., Static fatigue of high strength steel, *Trans. Amer. Soc. Metals* **48**, 198–212, 1956.

Tests were made on AISI 4340 steel to ascertain some of the causes of "static fatigue," the phenomenon of brittle failure of high-strength steels under prolonged static stress. The steel is produced by melting in air, in argon, or in vacuum (slight argon pressure) and treated to short-term strength levels of 230 or 280 kips. The ¼-in. diam test bars contained a 60° notch, 0.001-in. bottom radius. Tests up to about 10,000 minutes show: (1) No ap-

preciable effect due to melting practice despite higher hydrogen content of air melted samples. (2) No noticeable "static fatigue" in samples of lower strength level (230 kips). (3) Positive indication of static fatigue in higher strength samples (280 kips.) A stress of about 85% of short-time breaking stress causes failure in about 5000 minutes. Results are scattered rather widely.

The second series of the lower strength level (230 kips) steel were cadmium plated and tested either directly or after baking at 350 F for 1-½ hours. It is known that the plating process permits hydrogen to diffuse locally into samples and embrittles them in an ordinary tensile test, while subsequent baking is known to restore the short-term tensile values. The tests confirm this. They also show appreciable static fatigue in both baked and unbaked samples with an "endurance limit" at about 45% of the strength before plating.

These tests show little correlation between hydrogen contained in the steel and static fatigue. Nevertheless, reviewer wants to emphasize the statements by discussors and authors that hydrogen can have a pronounced effect in high-strength alloys but that the mechanism still remains to be discovered.

E. G. Chilton, USA

120. Newman, R. P., The influence of weld faults on fatigue strength with reference to butt joints in pipe lines, *Inst. mar. Engrs. Trans.* **68,** 6, 153–172, June 1956.

Fatigue tests have been carried out on lengths of 6-in. diam mild steel pipe containing welded butt joints. The condition of testing was alternating plane bending, developing stresses transverse to the joint. This test method was used to study the possible effects of certain types of weld fault included in some of the joints, fatigue stressing being regarded as probably the most critical condition for revealing such effects. Control data were established for a number of different types of good quality joint and, for comparison, further data were then obtained from tests on defective joints. The latter contained defects such as scattered porosity, "tramline" slag inclusions, lack of fusion, gross defects, lack of penetration and piping.

It is shown that, for the conditions applied, the root zone of welds, with and without backing rings, exercises a predominant influence on fatigue behavior. Except in the case of lack of penetration the defects had no significant effect on fatigue strength because of this overriding influence of the root zone, and hence no correlation between general radiographic appearance and fatigue behavior is possible. The lack of penetration, which existed as a continuous defect, had a decisive effect on strength.

From author's summary

121. Kaufman, A., and Meyer, A. J., Jr., Investigation of the effect of impact damage on fatigue strength of jet-engine compressor rotor blades, *NACA TN* 3275, 25 pp., June 1956.

An investigation was undertaken to determine the effect of type and location of impact damage on the fatigue strength of jet-engine compressor blades. First-stage compressor rotor blades from a production engine which had suffered foreign-object damage were fatigue tested. The results showed that the most serious damage to the blades, as measured by the reduction in fatigue strength, was nicks at the leading and trailing edges in the vicinity of the maximum-vibratory-stress section of the airfoil. The farther the damage was from this section, the smaller was the decrease in blade strength. Nicks and dents on the pressure surface of the airfoil away from the leading and trailing edges did not reduce the strength. Dents were less serious than nicks, and the strength of dented blades could be restored by reworking them. The strength of seriously nicked blades could not be reliably restored by reworking.

From authors' summary

122. Donelly, D., and Finney, J. M., The flexural fatigue properties of spin dimpled 75S-T aluminium alloy sheet, Dept of supply research & Dev. branch *Aero. Res. Labs. Melbourne, Austral. Note* ARL/SM 222, 6 pp. + 8 figs., Oct. 1955.

Flexural fatigue tests were made on unnotched, spin-dimpled and drilled hole specimens using 75S-T aluminum alloy sheet.

The results indicated that at high stresses the fatigue properties of the spin-dimpled specimens were inferior to both the drilled hole and unnotched specimens.

At low stresses, however, the spin-dimpled specimens gave superior fatigue properties to both the unnotched and the drilled hole specimens.

Comparison with previous tests on hot and cold coin-dimpled specimens showed that, at 10^5 cycles, there was no appreciable difference in fatigue strengths, but that at 10^7 cycles the spin-dimpled specimens were 17% stronger than the cold coin-dimpled specimens and 4% weaker than the hot coin-dimpled specimens.

From authors' summary

123. Shahinian, P., Influence of cold work on strength of steel at elevated temperatures, *Trans. Amer. Soc. Metals* **48,** 952–970, 1956.

Stress-rupture and relaxation tests made at elevated temperatures upon cold-worked (0 to 39% reduction in area) chromium-molybdenum steel bars indicate that rupture and creep strengths at 700F increase with increasing amounts of cold work. Tests at 800° and 900° indicate the existence of a critical value of cold deformation (between 8% and 15% reduction in area) below which the strength is lowered, while beyond the critical value increased strength is obtained. It is suggested that this behavior is due to the Bauschinger effect. Cold work had no apparent influence on rupture strength at 1000F, but creep strength decreased with increasing cold work. In relaxation at 900F, residual stress was lowered by increase in cold work.

J. E. Goldberg, USA

124. Schoeck, G., Dislocation theory of plasticity of metals, pp. 229–279, Advances in Applied Mechanics. Vol. IV (Dryden, H. L., von Karman, T., and Kuerti, G., editors), New York, Academic Press, Inc., 1956.

Objective of this topical review is a description of the mechanical behavior of a metal containing dislocations. The experimental facts and theoretical consideration leading to the introduction of dislocations are discussed. An integral equation for the displacements in the glide plane is given (assuming the interaction potential sinusoidal) and its solution for a simple cubic lattice, indicating that, since width of the dislocation is small, severe lattice distortion is confined to only a few atoms near the center of the dislocation line. Another section discusses general features, as type, (edge, screw), geometry, energy, and response to forces. Burgers vector, much used, gives "strength" of dislocation; is defined as contour integral of displacement. Sessile reactions, Frank-Read sources, half and extended dislocations are described. Stresses are obtained by means of the Airy stress function, resulting in an expression involving Burgers vector, Poisson's ratio, rigidity modulus, and a coordinate distance. The elastic or line energy can be obtained by the volume integral of the energy density or, more simply, as a surface integral, resulting in an expression involving rigidity, Burgers vector, a factor dependent on crystallographic orientation, the energy of atomic disorder, and a distance related to the dimensions of perfect regions in the crystal. The force on a dislocation results from the fact that applied surface stresses do work when dislocation moves in interior. Experimental evidence for dislocations is provided by electron micrographs of spiral growth, tilt boundaries, polygonization and three-dimensional networks; also by approach to theoretical strength of metal crystals whose diameter is of magnitude of distance between dislocations as found by x-ray measurements. Internal friction and change in elastic modulus are very sensitive to structure of dislocation network, density of dislocation, and distribution of their loop lengths. Many models are possible and none

appear to be completely satisfactory: at low frequencies and high temperatures, the locking impurity atoms can diffuse with moving dislocations; at higher stresses, dislocations can break away from impurities and travel with relative ease through the lattice.

Discussion includes several causes which could determine yield stress: Frank-Read source; long-ranged stress fields of the network; Peierl's forces; local obstacles; locking by elastic interaction with solute atoms; locking by chemical interaction in solid solutions; geometrical interaction in ordered alloys.

Discussion is also given of form of stress-strain, or work-hardening curve, its dependence on temperature and on crystallographic orientation; and the difference in work hardening in different structures. (Curve divided into three regions: (1) easy glide, (2) interaction, and (3) final); also of surface phenomena as slip lines, glide bands and deformation bands.

The yield strength of polycrystals often nearly reaches the theoretical strength, but plastic deformation occurs at much lower stresses and is mainly determined by movement of dislocations. Thus many strong obstacles, such as precipitate particles and grain boundaries, have to be present in such material. When the particles are finely dispersed the dislocations can pass easily through regions of high internal stress because the random forces acting on the dislocation line cancel. When particle size approaches the dislocation radius of curvature, the dislocations take a curved path through potential energy valley, avoiding regions of high stress. When particle size is larger than radius, the dislocations bulge out between particles, the loop coming together behind them, the particles being bypassed. Discussion of yield and fracture strengths with grain size leads to a relation between applied stress and grain diameter in agreement with observed fracture strengths.

Reviewer believes this to be an adequate, if brief, description of the topic. C. C. Osgood, USA

125. Ambrose, H. A., and Taylor, J. E., Wear, scuffing, and spalling in passenger-car engines, *SAE Trans.* **63,** 192–203, 1955.

Mechanical Properties of Specific Materials

(See also Revs. 111, 114, 122, 124)

Book—126. Campbell, I. E., editor, High-temperature technology, New York, John Wiley & Sons, Inc.; London, Chapman & Hall, Ltd., 1956, xiv + 526 pp. $15.

The rapid expansion of work in high-temperature technology has outstripped good surveys of the properties of materials and presents a need for this monograph. In it some 35 workers contribute articles on their specialities. It is inherent in such an arrangement that the completeness of the survey and the style vary considerably, but this is balanced by the authoritative treatment by specialists.

The articles are grouped under materials, method, and measurements. The articles on materials include a list of the properties at high-temperature of metals, oxides, carbon and graphite at high temperature, carbides, borides, silicides, nitrides, sulfides and cermets. The articles on oxides and cermets probably give the most practical information. Most important, an extensive bibliography adds to the usefulness of each article.

Under methods for achieving high temperatures, furnaces for resistance, induction, arc and solar heating are discussed. There is a brief but practical discussion of sintering. The final section of the book is on measurements, the mechanical and the physical properties of materials at high temperatures.

The articles present a compilation of physical properties for practical design purposes, while the techniques mix practical design information with purely experimental techniques. Most of the available information is presented in a readily usable form that is excellent for general design considerations and for reference in preparing experimental programs. The references provide an excellent guide for a more thorough study. F. Todd, USA

127. Campbell, J. D., and Duby, J., The yield behavior of mild steel in dynamic compression, *Proc. roy. Soc. Lond. (A)* **236,** 1204, 24–40, July 1956.

Authors provide further information on the behavior of mild steel subjected to compressive impact loading. They present description of the impact machine, reproductions of oscillographs of strain time, and pictures of the microstructure of the metal. The pictures represent condition of the metal before test, after dynamic yielding, and after static yielding. This pictorial evidence seems to indicate differences in plastic flow at high and low rates of loading. Theories of yield in terms of dislocations are discussed. Resistance-wire strain gages were used in the experiments. Some discussion is given on wave shape and dispersion.

Reviewer is of the opinion that the microstructure study is probably the most important contribution of this generally interesting paper. W. H. Hoppmann, II, USA

128. Horst, R. L., Aluminum alloys (Tenth annual materials of construction review), *Indust. Engng. Chem.* **48,** 9 (part II), 1696–1701, Sept. 1956.

129. Mitchell, L., Ceramics (Tenth annual materials of construction review), *Indust. Engng. Chem.* **48,** 9 (part II), 1702–1709, Sept. 1956.

130. Fisher, H. L., Elastomers (Tenth annual materials of construction review), *Indust. Engng. Chem.* **48,** 9 (part II), 1710–1720, Sept. 1956.

131. Grove, C. S., Jr., Casey, R. S., and Vodonik, J. L., Fibers (Tenth annual materials of construction review), *Indust. Engng. Chem.* **48,** 9 (part II), 1721–1730, Sept. 1956.

132. Roll, K. H., Lead and its alloys (Tenth annual materials of construction review), *Indust. Engng. Chem.* **48,** 9 (part II), 1731–1734, Sept. 1956.

133. Sherwood, E. M., Less common metals (Tenth annual materials of construction review), *Indust. Engng. Chem.* **48,** 9 (part II), 1735–1741, Sept. 1956.

134. Fuller, R. M., Nickel, including high-nickel alloys (Tenth annual materials of construction review), *Indust. Engng. Chem.* **48,** 9 (part II), 1742–1759, Sept. 1956.

135. Seymour, R. B., Plastics (Tenth annual materials of construction review), *Indust. Engng. Chem.* **48,** 9 (part II), 1760–1774, Sept. 1956.

136. Luce, W. A., Stainless steels including other ferrous alloys (Tenth annual materials of construction review), *Indust. Engng. Chem.* **48,** 9 (part II), 1775–1787, Sept. 1956.

137. MacIntosh, R. M., Tin and its alloys (Tenth annual materials of construction review), *Indust. Engng. Chem.* **48,** 9 (part II), 1788–1793, Sept. 1956.

138. Bomberger, H. B., Titanium (Tenth annual materials of construction review), *Indust. Engng. Chem.* **48,** 9 (part II), 1794–1797, Sept. 1956.

139. Baechler, R. H., Wood (Tenth annual materials of construction review), *Indust. Engng. Chem.* **48,** 9 (part II), 1798–1801, Sept. 1956.

Plasticity, Forming and Cutting

(See also Revs. 110, 117)

140. Creveling, J. H., Jordan, T. F., and Thomsen, E. G., Some studies of angle relationships in metal cutting, ASME advance paper no. 55-A-125, 14 pp., + 8 Tables, 20 Figs., 1955.

Free cutting steel, SAE 1113, in the annealed, and SAE 1113 and SAE 4135 in the cold-rolled condition were studied in orthogonal metal cutting. The feed was varied from 0.002 to 0.010 in. per revolution (ipr) and the rake angle from 20 to 40 deg, at a surface speed of 30 fpm, using several cutting fluids. This range of rake angles and feeds was in the practical region and permitted obtaining continuous chips. When examining the current theories on the shear angle ϕ, rake angle α and friction angle β relationships, it was found that none was in complete agreement with the experimental results. It appears that at this time the knowledge of the theory of plastic deformation as applied to metal cutting is insufficient to allow derivation of a unique theoretical solution which incorporates all variables. However, the equation $\lambda = \phi + \beta - \alpha =$ const was found to hold approximately for the limited range of variables investigated. It was further found that the friction process on the tool face can be explained satisfactorily as a metal-shearing process, and that the ratio of the shearing stresses on the shear plane and tool face was approximately constant for the experimental data obtained.

From authors' summary by J. Frisch, USA

141. Finnie, I., Review of the metal-cutting analyses of the past hundred years, *Mech. Engng.*, N. Y. **78**, 8, 715-721, Aug. 1956

142. Loewen, E. G., and Cook, N. H., Metal cutting measurements and their interpretation, *Proc. Soc. exp. Stress Anal.* **13**, 2, 57-62, 1956.

Authors describe the development of a tool dynamometer of which the essential requirements are that it must be very stiff and at the same time be capable of resolving the tool force into its orthogonal components.

Apart from its use for the study of the mechanism of the cutting process and of particular machining operations, the dynamometer is likely to prove useful on automatic machine tools as the indicator of incipient tool failure.

A. F. C. Brown, England

143. Senior, B. W., Flange wrinkling in deep-drawing operations, *J. Mech. Phys. Solids*, **4**, 4, 235-246, Aug. 1956.

Author develops a simple theory for estimating the critical dimensions of a deep-drawn flange and the number of waves into which it will collapse on wrinkling. Included in the analysis are the effects of varying geometry of the flange, different material properties, and different types of blankholding pressure (zero, proportional to displacement, and constant). Comparison between theory and practice is made by reference to a comprehensive series of experimental results, which provide convincing proof of validity of the analysis.

Reviewer believes paper should be valuable to both designers and users of deep-drawing presses. There are several typographical errors; notably, Fig. 4 is, in fact, the Fig. 5 referred to in the text, and vice versa. Also in the legend of the true Fig. 4, the broken line should represent the predicted behavior of the 0.012-in. material and not the 0.036-in. material, as shown.

J. M. Alexander, England

144. Thomsen, E. G., Comparison of slip-line solutions with experiment, *J. appl. Mech.* **23**, 2, 225-230, June 1956.

See AMR **9**, Rev. 1130.

145. Bishop, J. F. W., An approximate method for determining the temperature reached in steady motion problems of plane plastic strain, *Quart. J. Mech. appl. Math.* **9**, part 2, 236-246, June 1956.

During plastic distortion of metals most of the work expended reappears as heat. It is of the first importance to know the resulting temperature changes and approach to steady conditions in metalworking processes. Calculation is very difficult and has not hitherto been seriously attempted when conduction and heat transport are taken into account.

Paper opens up many possibilities by new approach that makes it possible to handle the mathematical problem numerically. Practicability of method is illustrated by calculation of isothermals in sheet-extrusion process, using flow lines and energy dissipation given by slip-line field theory for rigid-plastic solids.

R. Hill, England

146. Thomsen, E. G., Plasticity equations and their application to working of metals in the work-hardening range, *Trans. ASME* **78**, 2, 407-412, Feb. 1956.

Article presents a brief discussion of true stress for unidirectional stress and points out that the three-dimensional case is difficult. A presentation of three-dimensional true-stress true-strain may be found in the doctoral thesis by W. E. Cooper of Purdue University, August 1951.

The author's use of the visible traces of plastic flow is both unique and effective. It provides remarkable agreement between compressive test data and data from actual extrusion and suggests a way of predicting the amount of flow and, consequently, the amount of strain hardening present in extrusions. Of course, one must always bear in mind that at extrusion temperatures the strain hardening is greatly relieved with time in the presence of the temperatures existing in the extruded shape immediately after passing through the die.

This paper is good reading when coupled with several other papers by the author dealing with the same type of problem.

R. G. Sturm, USA

147. Griffin, E., Cold roll-forming and manipulation of light-gauge sections, *J. Inst. Metals* **84**, 181-197, 1955-1956.

The advantages are outlined of using cold forming as a method for producing in large quantity, sections of complicated profile from strip. The forming process itself is described in detail, with accounts of the types of machine used and their capacities, calculation of power requirements, and the design and manufacture of roll-forming tools. The operation of cold-roll-forming machines is then dealt with, and the use of press brakes for forming simple sections is discussed.

The manipulation of cold-roll-formed sections is described, and, finally, details are given of the finishing procedures used in the production of aluminum-alloy slatting for Venetian blinds.

From author's summary

148. Siegel, A., Automatic programming of numerically-controlled machine tools, *Control Engng.* **3**, 10, 65-70, Oct. 1956.

Hydraulics; Cavitation; Transport

(See also Revs. 177, 184, 262, 264, 351, 356)

149. Kozak, M., Some methods of analysis of unsteady flow in open channels (in Hungarian), *Hidrológiai Közlöny* **36**, 1, 17-32, Feb. 1956.

Methods of integration of differential equations for gradually varied unsteady flow are represented. They are based on developments by Russian scientists, such as N. M. Bernadskii (1933), S. A. Khristianovich (1938), and V. A. Arkhangelskii (1947). Graphical methods for establishing relationships of different variable parameters are particularly emphasized.

S. Kolupaila, USA

150. **Bogardi, J., Variation of bed load characteristics along with the current** (in Hungarian), *Res. Inst. for Water Resources, Budapest, 1954 Report,* 51-64, 1955.

Observations in Danube River show that the size of silt gradually diminishes downstream, along with decrease of the velocity of flow. Relationship between the bed load and mean velocity in Danube and in Tisza is established, as also between the bed load and water discharge. S. Kolupaila, USA

151. **Puskas, T., Some lessons drawn from river discharge statistics** (in Hungarian), *Res. Inst. for Water Resources, Budapest, 1954 Report,* 90-99, 1955.

Daily observations and use of a discharge curve give accurate runoff in large rivers; gradually varying bottom does not particularly complicate computations. In small rivers, stage observation once a day is unreliable, as periodical fluctuations are possible. Changes in the bed can cause errors as large as 250%. Influence of nonuniform flow can also be of particular importance in these conditions. S. Kolupaila, USA

152. **Scheidegger, A. E., Correlation tensors in statistical hydrodynamics in porous media,** *Canad. J. Phys.* 34, 7, 692-698, July 1956.

Author's statistical theory of flow through porous media, based upon an extremely simple model in which pressure fluctuations are being neglected, has been criticized because velocity correlation tensors had not been introduced as dynamical variables. It is shown in the present paper that the introduction of such variables is not useful in author's theory. This is due to the particularly simple nature of the model employed and does not imply that use of correlation tensors may not lead to something useful in other conceivable statistical theories.

From author's summary

153. **Apelt, C. J., Investigations of water hammer at the University of Queensland,** *J. Instn. Engrs. Austral.* **28,** 3, 75-81, Mar. 1956.

A program of research by the University of Queensland Engineering Department has resulted in the development of electronic equipment with negligible inertia effects which can record, with accuracy, the rapid pressure changes associated with the occurrence of water hammer in pipelines.

The apparatus has been employed in investigations of two pump rising mains near Brisbane. The investigations verified that the elastic column theory of water hammer can be applied with confidence, in general, but that in its present form it cannot cope with phenomenon of separation of the water column. It was found, also, that important simplifications can be allowed in the calculation of water-hammer surges in complicated pipe layouts without causing too great a loss in accuracy for design work.

From author's summary

154. **Mellen, R. H., An experimental study of the collapse of spherical cavity in water,** *J. acoust. Soc. Amer.* **28,** 3, 447-454, May 1956.

The pressure wave produced by the collapse of an electrically generated spherical cavity (~1 cm in radius) in water was measured by means of a small electroacoustic hydrophone ($^1/_{16}$ in. in diameter) at a distance of 50 cm. The pressure was found to increase as the bubble collapsed according to the $t^{-4/5}$ (time) law in the interval corresponding to subsonic flow. The pressure then suddenly jumped to a higher value and rapidly decayed to zero. This rapid increase in pressure is assumed to be a shock wave. Using Gilmore's theory for collapse of the cavity and finite amplitude-wave theory for the pressure wave, author finds that the value of the pressure-amplitude characteristic at the shock front corresponds to a cavity-wall velocity approximately equal to the velocity of sound. Since the shock wave has been attenuated, the peak wall velocity must be greater than this value.

From author's summary

The following 22 papers, (Revs. 155-176) were taken from the Symposium on Cavitation in Hydrodynamics, *Nat. Phys. Lab., London; Her Majesty's Stationery Office, 1956.*

155. **Eisenberg, P., A critical review of recent progress in cavitation research,** Pap. no. 1, 16 pp.

This review is a continuation of former publications of the author [*David W. Taylor Mod. Basin Reps.* 712, (1950) and 842, (1953)] with the aim to formulate the basic problems in the field of cavitation, to summarize the results of research from a critical point of view, and to disclose, from this critical review, the presently urgent questions. This aim has been well achieved.

Discussing first the theory of entrained gas nuclei and their stability, and stressing the need for a method of measuring nuclei content, author proceeds to shear flow phenomena and the effect of turbulence on the cavitation process. A great part of the paper deals with problems on scale effects, particularly with that of scaling cavitation onset. A chapter on the dynamics of transient cavities and collapse pressures, including compressibility effects, follows. Further, steady-state cavities are discussed distinguishing between cavitation in a wake flow and truly free-streamline flow. Considerations on the mechanics and theories of cavitation damage conclude the paper, to which a list of publications on the subject during 1951/54 is attached. H. W. Lerbs, Germany

156. **Williams, E. E., and McNulty, P., Some factors affecting the inception of cavitation,** Pap. no. 2, 22 pp.

Paper is concerned with yet another attempt to find the effect of air content on cavitation inception in water; included also are results of some experiments on the "velocity scale effect" and on the influence of dissolved sodium nitrite (a corrosion inhibitor) on inception. All observations were made on a symmetrical strut (2-in. chord) having a cylindrical forebody ($^1/_2$-in. diam) and wedge-shaped afterbody spanning the test section (2-in. wide × 1-in. high) of a small water tunnel. In general, it was found that the critical cavitation number increases with increasing air content, in agreement with previous investigators; compare, e.g., Crump, AMR **4**, Rev. 4190. Again the data exhibit large scatter characteristic of such experiments. A velocity scale effect of the type observed by Kermeen et al [AMR **9**, Rev. 182] was also found, i.e., increasing critical cavitation number with increasing velocity.

Of particular interest are observations of periodic growth and collapse of the cavitated region similar to previous observations by Shal'nev [AMR **8**, Rev. 2754] and Knapp (title source), for example, but, in this case, oscillating alternately on either side of the profile with frequency increasing both with velocity and pressure. Reviewer suggests latter phenomenon is consequence of asymmetrical flow patterns resulting from induced circulation on the resultant profile (strut plus cavity) combined with the associated effects of the restricted channel.

P. Eisenberg, USA

157. **Ziegler, G., Tensile stresses in flowing water,** Pap. no. 3, 10 pp.

Author has made still another attempt to determine the dependence of cavitation inception pressures on total air content. Observations of onset of cavitation in a nozzle having a throat area of 20 sq cm are presented. Results

are generally of the character found by Crump in 1949 [AMR **4**, Rev. 4190], including evidence of small tensions. As usual, the data exhibit very large scatter, which, surprisingly, is attributed primarily to errors in measurement. To reviewer, this conclusion indicates lack of recognition by author of the probable behavior of gas or vapor nuclei required for inception; see, e.g., Eisenberg, AMR **7**, Rev. 162. However, author is evidently aware of present views that nuclei are required for cavitation to occur.

P. Eisenberg, USA

158. **Daily, J. W., and Johnson, V. E., Turbulence and boundary layer effects on cavitation inception from gas nuclei,** Pap. no. 4, 19 pp.

An experiment is described in which cavitation bubbles were observed and studied in the turbulent boundary layer on the flat top wall of the test section of a water tunnel. Free-stream velocity was 27.5 fps. Bubbles were photographed at rates from 2000 to 3000 frames per sec. As pressure was reduced, bubbles of diameter from about 0.002 in. to 0.16 in. were recorded, rapid growth being observed when critical size was reached. The data include estimates of turbulence intensity from the motion of the bubbles, distribution of bubbles within layer, and wall pressure for cavity inception and growth. The more significant results were: (1) That cavity growth occurred at mean pressures above critical; and (2) that the maximum number of cavities was found in the central portion of the layer.

Authors conclude that result (1) can only be attributed to local pressure reduction due to turbulence, yet point out that estimated pressure fluctuations are too small and that relatively few cavities pass near wall where turbulent velocity fluctuations reach maximum. A rationalizing argument is advanced, with some supporting evidence, that the turbulence has a structure of discrete eddies with size about boundary-layer thickness and centers near the middle of the layer, and that cavities are transported toward the center of the eddies and advance there in a low pressure environment.

Reviewer believes this to be an oversimplified picture of turbulence structure; but considering the little we know about pressure fluctuations, the argument may have merit relative to cavity behavior. It is no reflection on this work to say that the question can stand further investigation.

G. B. Schubauer, USA

159. **Davies, R. M., Trevena, D. H., Rees, N. J. M., and Lewis, G. M., The tensile strength of liquids under dynamic stressing,** Pap. no. 5, 20 pp.

In spite of clever methods for producing and measuring stress waves in liquids in an attempt to determine tensile strengths under dynamic loading, authors have come no closer to achieving definitive measurements than previous investigators. Stress waves were produced by firing a 0.22-caliber lead bullet against a piston fitted to the bottom of a tube containing boiled, distilled water. In a first series of experiments, tensions resulted from the motion— produced by reflection of the compression wave—of a similar, free piston at the top of the water column. The pressure in the liquid was then derived from analysis of the displacement-time history of this upper piston. In a second method, direct measurement of the tension was tried, using a pressure bar inserted into the side of the tube and fitted with gages responding to the longitudinal stress waves in the bar; tensions were produced by allowing reflection of the compression wave from a free water surface. While a very wide range of limiting values was recorded, the highest values being attributed to experimental errors, it is concluded that the critical tension for water in contact with steel or duraluminum is probably of the order of 10 atm. In a note added after completion of the paper, experiments are cited in which tensions ranging from 16 to 40 atm were measured following modifications to the sensing face of the pressure bar.

While the many difficulties in measurement technique plaguing the authors were certainly major factors in preventing attainment of meaningful results, in reviewer's opinion it will be necessary also to characterize contained nuclei, which must inevitably be present in a quantity and size depending on the method of sample preparation, before definitive conclusions will be possible in such experiments.

P. Eisenberg, USA

160. **Strasberg, M., Undissolved air cavities as cavitation nuclei,** Pap. no. 6, 13 pp.

Perhaps the most important—and least understood—aspects of the problem of cavitation inception (and of the tensile strength of liquids generally) are those of the origin, nature, and behavior of gas nuclei which are evidently required for initiation of cavitation (or fracture). It has been suggested that rational predictions of inception pressures must eventually depend on a knowledge of the mechanism of nucleus stabilization and on development of methods for characterizing nuclei content [Eisenberg, AMR **4**, Rev. 2546; **7**, Rev. 162]. In reviewer's opinion, the work reported in this paper constitutes the most important contribution in recent years toward achieving these goals.

Following a review of previous work on the behavior of gas and vapor nuclei in an ultrasonic field, author describes experiments designed to (a) detect undissolved air nuclei in water using ultrasonic absorption and (b) determine critical pressures for cavitation onset in water as a function of air content. All of the experiments were conducted in undisturbed water. From the relations between bubble size and sound energy absorption in water containing bubbles, it is possible to deduce the number of bubbles of a given size in a given volume of liquid. Values of the minimum detectable number and concentration of cavities at several sound frequencies are tabulated, and the decrease in rate of sound energy decay as a function of the number of hours after sampling is shown. The former results indicate the limitations of the apparatus, while the latter gives a clue to the maximum size, at least, of the nuclei which might exist in water after absorption of the gas even under saturated conditions.

Assuming that the nuclei are stabilized either in crevices on solid particles or by an "organic skin" at the interface between gas and liquid, which at equilibrium prevents diffusion into the liquid, author states result that critical pressure for cavitation is $P_c = aG - bP_m$, where G is the equilibrium or saturation pressure of the air dissolved in water, P_m the maximum external water pressure to which the cavity has been subjected, and a and b are constants. (The assumptions basic to this result are contained in Fox and Herzfeld, *J. acoust. Soc. Amer.*, **26**, 1954; the explicit derivation is given in the author's doctoral dissertation, Catholic Univ., 1956, which, unfortunately, is not referenced.) Measurements were made of ultrasonically induced cavitation at the center of a spherical flask. The results show remarkably little scatter for ratios of air/water volume as low as 0.01 with fairly large (though, for this type of experiment, comparatively small) scatter at smaller dissolved-air contents. The values of the constants a and b are given as about 4 and between 2 and 3, respectively. These results tend

to indicate that whatever mechanisms are responsible for nucleus stabilization, i.e., those on which the linear prediction for P_c is based or others, the tendency is to behave as predicted for the postulated ones; further, that for such mechanisms, the equilibrium conditions (dissolved air versus measurable bubbles) are predictable.

While it seems unlikely that such equilibrium conditions can obtain in flowing liquids, except under very restricted conditions, the methods of the author are, to the reviewer's knowledge, the first ones reported that might be used successfully for investigating (by sampling) the relations between nuclei and inception pressures in flowing liquids.

P. Eisenberg, USA

161. **Appel, D. W., Instrumentation for the measurements of fluctuating forces, pressure intensities, and velocities in studies of cavitation,** Pap. no. 7, 9 pp.

Short general descriptions are given of a three-component balance for a water tunnel, of a Pitot-type total head meter, and a (hot-) platinum film velocity meter, which is mounted on a cylindrical, round-nosed glass rod. The calibrations given in the paper are insufficient for its use in measuring transient or fluctuating phenomena.

H. A. Einstein, USA

162. **Ellis, A. T., Techniques for pressure pulse measurements and high-speed photography in ultrasonic cavitation,** Pap. no. 8, 32 pp.

A photographic system has been developed and applied to the study of cavitation bubble collapse. Sequences of 700 pictures at a rate of one million pictures per second and less than 10^{-7}-sec exposure time have been obtained. Resolution is estimated to be better than 10^{-3} cm. Photoelastic photographs have also been taken under the above conditions.

Ultrasonic cavitation bubbles have been photographed collapsing on the surface of a photoelastic solid, and the resulting strain wave in the solid has been observed in the photographs.

Dynamic properties of a photoelastic material have been obtained in order to permit quantitative measurement of transient waves in solids by this method.

Photocell detection of photoelastic strain fringes has provided information on the duration of strain pulses in a solid due to cavitation bubble collapse.

From author's summary

163. **Ritter, H., Instrumentation for the A. R. L. water tunnel and rotating beam channel,** Pap. no. 9, 15 pp.

Descriptions and characteristics of instrumentation developed specifically for the very impressive slotted-wall cavitation tunnel (30-in. test section) and rotating arm facility of the Admiralty Research Laboratory, Teddington, England (see e.g., *Shipbldg. and Shipping Record* Dec. 8, 1955, p. 733) are presented. For force and moment measurements on underwater bodies, balances for internal installation are favored. Resistance strain gages, bonded to cantilever elements, are used exclusively in the balances and waterproofing is achieved successfully by means of layers of glass cloth and Araldite. Pressure transducers also employ such elements for detecting the motion of metal bellows. An "electromagnetic manometer" (inductance gage), which measures stagnation pressure at the model, is used to monitor the automatic speed controls for both facilities. Flow direction is measured with a very compact body of revolution (0.55-in. diam, 1.1 in. long) comprising a transformer with a single primary winding on a central magnetic core which is free to rotate relative to four fixed pillars on which are the secondary windings, thus giving a signal when disposed asymmetrically.

P. Eisenberg, USA

164. **Straub, L. G., Ripken, J. F., and Olson, R. M., The six-inch water tunnel at the St. Anthony Falls Hydraulic Laboratory and its experimental use in cavitation design studies,** Pap. no. 10, 11 pp.

A recirculating model water tunnel has been devised at the St. Anthony Falls Hydraulic Laboratory for the purpose of determining prototype design data for use in the planning of various types of cavitation test facilities. The test section of the model is 6 in. in diameter, and various boundary geometries have been studied in their relation to the test stream-flow quality. Special emphasis has been given to the cavitation test limits imposed by the test-section boundaries and various other tunnel components. This paper describes the basic tunnel, the critical cavitation tests made on the tunnel, and some cavitation studies made in the tunnel. Observations made on closed (cylindrical and diverging), open, and slotted-wall test sections are discussed. A minimum cavitation index of about 0.023 can be achieved in the diverging closed-jet test section at a velocity of 50 ft/sec.

Some cavitation studies indicate how the cavitation susceptibility of the tunnel water varies, and show that the critical cavitation index of a slender body is more constant when based on a measured pressure than when based on vapor pressure.

From authors' summary

165. **Gerber, H., Some reflections on model scale formulae for cavitation phenomena,** Pap. no. 11, 13 pp.

This interesting paper deals with cavitation testing of models of Kaplan turbines from their early stage (1925-30) to date, particularly at the Esher-Wyss plant in Zurich. There is a troublesome criterion, the Froude number, which is expressed here as the ratio of the net head and the runner diameter (H/D). If this is the same as required for model and prototype, either the power becomes too small for the accepted model sizes (8 in.-20 in.) or needs an inlet pressure below atmospheric, which brings undesirable complications in the setup. For these reasons the Froude criterion was disregarded and tests made at the prototype head. These proved satisfactory sometimes, but in other cases showed an erratic influence of the test head. (Mr. Duport of the Grenoble Laboratories attributes this, in the "Discussions", to varying shapes of the cavitation coefficient curve along the blade profile.)

To account for the time element in cavitation, $(H/D)^{1/2}$ is considered in place of H/D. This and other suggestions clearly indicate the need of further research.

Reviewer's reaction is that a new edition of the Hydraulic Machine Laboratories part of Dr. Freeman's monumental "Hydraulic Laboratory practice" (1925, 1929), on the same international scale, would hasten the solution of the problem.

A. Hollander, USA

166. **Cox, R. N., and Clayden, W. A., Air entrainment at the rear of a steady cavity,** Pap. no. 12, 19 pp.

Steady-state cavities may be formed behind obstacles in a stream by vaporization of the liquid under low pressures or artificially by introduction of gases into the cavity region, as, for example, in the case of the exhaust gases from an underwater propulsion unit. In the latter case, gas must be supplied continuously, the size of the cavity being determined by the rates of gas inflow and entrainment (i.e., discharge) at the rear of the cavity. At low cavitation numbers (defined on the basis of cavity pressure), experiments have shown that a pair of vortex tubes are formed and trail off behind the cavity carrying the gas

flow; these conditions correspond to high entrainment rates. Authors postulate that such vortex pairs play an important role in establishing the equilibrium entrainment rate, and develop a theory for predicting the size of these tubes and their gas discharge capacity. Due to the buoyancy force on the main cavity, the velocity on the upper surface must be less than on the lower, the cavity pressure being assumed constant. The circulation is then computed, assuming the cavity be long compared with its diameter. By equating the resulting lift force on the vortex pair (as in airfoil theory) to the buoyancy force, the separation of the vortexes is found, assuming the cross sections remain circular. Assuming turbulent air flow in the core of each vortex, the mean velocity and an entrainment coefficient are found as functions of a Froude number F_1, based on cavity length l, and another Froude number defined on core diameter.

The theoretical results are compared with water-tunnel experiments in which air was injected behind disks. The predictions of entrainment rate as function of the parameter $F_1\,\sigma^{1/4}$, where σ is cavitation number, agree fairly well with the experimental results for entrainment coefficients, $C_Q = Q/Ud^2$ (Q volume rate of air flow; U stream velocity; d maximum diameter of cavity), above 0.1. Below this value, the vortex tubes break up into small bubbles. At very small values, entrainment is diminished, gravity effects become less important, and the flow changes to the familiar re-entrant jet configuration.

A more exact analysis of the vortex pair flow, taking into account distortion of the core cross section, is given in an appendix by A. H. Armstrong.

P. Eisenberg, USA

167. Silverleaf, A., Preliminary observations on a geometrically-similar series of model screws, Pap. no. 13, 9 pp.

Author reports initial measurements of performance and cavitation characteristics of a geometrically similar series of four marine propeller models having diameters of 6, 8, 10, and 12 in. Under noncavitating conditions, the thrust and torque coefficients as function of advance coefficient (*forward velocity/(speed of rotation × diameter)*) were independent of both rotation speed and forward velocity, separately, for three different rotation speeds. On the other hand, for well-established cavitation, under conditions corresponding to the design thrust coefficient when not cavitating, the thrust and torque coefficients generally showed an increase with increasing speed of rotation. Both coefficients showed an initial increase with decreasing cavitation number before deteriorating. The latter is described as characteristic of events when only individual cavitation bubbles are present and before steady, fixed cavities develop.

Author seemingly overlooks possibility that profiles with relatively thin leading edges exhibit similar behavior with fully developed fixed cavities.

P. Eisenberg, USA

168. Weeks, A. F., Ship propeller cavitation patterns, Pap. no. 14, 15 pp.

Attainment of rational model-prototype correlations for marine propellers operating under cavitating conditions is severely handicapped by the difficulties of direct full-scale observations. This paper summarized the methods used by the Admiralty Experiment Works during the past few years in a correlation program on destroyers and fast patrol boats. The type of lighting used, the design of cameras, and characteristics of film emulsions developed for the purpose are described. In addition, the problems of installing adequate viewing ports, finding sea conditions suitable for such photography, and identification of propeller blade position and cavitation zones are discussed. A number of photographs are reproduced to illustrate some typical cavitation patterns obtained during the program, including face, back, and hub and tip vortex cavitation. While several general remarks are made regarding the relation of the prototype and model cavitation onset points and developed patterns—in particular, that cavitation was generally observed on the prototype at higher cavitation numbers than predicted by the model—the propeller characteristics, dimensions, and profile shapes are omitted entirely.

P. Eisenberg, USA

169. Plesset, M. S., and Parkin, B. R., Hydrofoils in noncavitating flow, Pap. no. 15, 15 pp.

Two domains of the two-dimensional flow past a hydrofoil are treated: very shallow submergence and very deep submergence. The depth of the water is considered as infinity. For sufficiently small Froude number, the pressure coefficients in the domain of shallow submergence are found to be limited and this limit is well described by a previous rule of E. V. Laitone. For high Froude numbers, this rule is found not to be applicable. The domain of sufficiently deep submergence has been treated theoretically by T. Y. Wu previously and the real occurrence of the cavitation is found to be quite well covered by this theory. For sufficiently deep submergence, the influence of the Froude number apparently may be disregarded. An exact hydrodynamic theory including arbitrary submergence and water depth is still missing even in the range of very high Froude numbers, but seems to the reviewer to be quite within the realm of practical realization. For finite Froude numbers, however, even simpler problems of free surfaces than the doubly-connected domain of a hydrofoil with or without cavitation have not yet found exact analytical solutions.

Author preferred the use of T. Y. Wu's extension of A. Roshho's model of separated flow. Reviewer does not think that the results of Riabauchinsky's or Gilbarg's models would have compared less favorably to the test results. If, however, the downstream extension of the range of cavitation would have been the objective of the problem, then undoubtedly Riabauchinsky's model should have deserved the preference, as has been previously proposed by reviewer.

F. Weinig, USA

170. Tulin, M. P., Supercavitating flow past foils and struts, Pap. no. 16, 19 pp.

In a previous paper [AMR **7**, Rev. 163], author announced a first-order linearized theory which results in reducing the problem of calculating cavity shapes and drag for nonlifting slender bodies in supercavitating flows (i.e., flows with long trailing cavities) to one of quadratures. The present paper gives another impressive collection of new theoretical results on supercavitating flows—not the least of which is a linearized theory for lifting surfaces published for the first time in the open literature.

Using the powerful "hydrodynamic comparison theorem" [Gilbarg, AMR **5**, Rev. 3486], author shows that, for a given thickness and volume, the strut and body of revolution of minimum drag at zero cavitation number are those for which the forebody shapes are formed by a plate and disk, respectively, placed normal to the stream, and the contiguous free streamlines. (Similar results have been found by Serrin, AMR **7**, Rev. 176.) Within the framework of the linearized theory, the forebody having characteristics similar to the above is parabolic; the superiority of this shape is illustrated by comparison with the straight-sided

wedge of the same length—drags being in the ratios of 0.62, 0.29, and 0.26 for equal thickness, equal volume, and equal maximum bending stress, respectively.

The linearized lifting-surface theory for supercavitating hydrofoils is based on the assumption that the magnitudes of the perturbation velocities due to the body are small compared with the stream velocity (as in thin-airfoil theory), i.e., valid for small angles of attack. To solve the hydrofoil problem with cavitation number zero, the physical plane is mapped into the $\overline{Z}$-plane by the transformation $Z^{1/2} = -\overline{Z}$, Z being the complex variable $x + iy$. The boundary conditions in the transformed plane are shown to be those of the linearized theory for flow past a cambered airfoil having a shape $\bar{x}d\bar{y}_0/d\bar{x} = \bar{x}^2 dy_0/dx$, (x, y_0) and $(\bar{x}, \bar{y}_0)$ being the offsets of the hydrofoil in the real and transformed planes, respectively. Thus, the solution in the $\overline{Z}$-plane is known. Very useful, simple, equivalence results are derived for the relations between the lift, drag, and moment of the cavitating foil and the lift, moment, and third moment of the "equivalent" airfoil. Using these results, author derives the optimum lift-drag ratio for a supercavitating foil of given lift coefficient C_L at zero cavitation number: $(L/D)_{\text{opt.}} = 8\pi/C_L$. For the flat plate, the solution of the linearized problem is given for arbitrary, finite, cavitation numbers. Numerical values of the lift coefficient as function of cavitation number and angle of attack are given.

The importance of Tulin's linearized theories in the field of cavitation is, in reviewer's opinion, of a rank equivalent to that of the thin airfoil and linearized airship theories in aeronautics and Michell's thin ship theory in naval architecture. In spite of the fact that it has not been widely available, the work of the author has already stimulated an impressive number of researches along these lines, both in the U. S. and abroad.

P. Eisenberg, USA

171. Numachi, F., Effect of static pressure difference on the cavitation characteristics of hydrofoil profile. (Report 2. The case of high static pressures), Pap. no. 17, 13 pp.

In a previous paper [*Inst. High Speed Mech., Tōhoku U.*, **5**, Rept. 42, 1955), author reported effects of absolute head variations on performance characteristics of hydrofoils at pressures less than atmospheric. The present paper reports an extension of these tests to pressures above atmospheric to determine validity of claimed necessity for running medium-head turbine models at or near prototype heads.

On basis that the profile is the dominating factor in determining performance, tests were made with a Clark Y profile under absolute heads ranging from about 1–1/3 to 3 atmospheres and with constant air content. Over the entire range, including the previous results obtained under heads as low as 400 mm Hg abs, no significant dependence on absolute head of lift-drag ratio was noted when cavitating or cavitation breakdown point was found—small changes being attributed to the variation in Reynolds number associated with speed changes required to fix cavitation number.

A slight increase in incipient cavitation number with increase in head was noted. P. Eisenberg, USA

172. Callis, G. T., A suggested mechanism of erosion damage, Pap. no. 18, 11 pp.

The various explanations of the damage associated with cavitation are reviewed, and attention drawn to observations in practice and in experimental work for which the explanation based upon a mechanical action due to cavity collapse is inadequate.

A brief description is given of the action of, and damage caused by, impingement attack, and attention drawn to the similarity between this and cavitation damage. It is suggested that it is not the collapse of cavitation voids but the severe turbulence of a cavitating condition which is the prime cause of the damage, and that cavitation damage is due to an action basically identical with that of impingement attack, with turbulence of the liquid as the major factor.

Cavity collapse may cause loss of material by a secondary action, and is the only feature of difference between cavitation damage and impingement attack. The suggested mechanism, bringing cavitation damage into line with other manifestations of corrosion-erosion, as primarily a dynamic corrosion process, provides a rational explanation of those facts which are not in consonance with a mechanical action theory. From author's summary

173. Knapp, R. T., Further studies of the mechanics and damage potential of fixed-type cavities, Pap. no. 19 14 pp.

Results of high-speed water-tunnel experiments, including quantitative measurements for series of geometrically similar bodies of revolution and qualitative measurements for two-dimensional sections, are reported. Stages of cavity growth, filling, and breakoff as observed by high-speed motion pictures are described and a physical explanation of cycle mechanics is proposed. Brief discussion of requirements for cavity similarity is given. Damage from pitting is discussed from standpoint of mechanics of process, type of failure (evidently not fatigue), factors determining cavity size, effect of flow velocity on pitting rate, and effect of guide surface shape. Interesting photographs of cavities are given in addition to test and calculated data.

Paper represents important contribution to knowledge of cavitation. C. W. Smith, USA

174. Rasmussen, R. E. H., Some experiments on cavitation erosion in water mixed with air, Pap. no. 20, 25 pp.

Rotating disk and flow-tube apparatus are described. In flow tube, erosion on cylindrical test pieces occurs only for a limited range of velocities. In all cases erosion almost stopped with addition of 8–10 per thousand by volume of small air bubbles. Much less air greatly diminished erosion. J. C. Geyer, USA

175. Wheeler, W. H., Mechanism of cavitation erosion, Pap. no. 21, 31 pp.

Author reviews earlier work on the role of chemical action in cavitation erosion. He then describes vibration experiments in which distilled water, KCL solution, and toluene were used to erode various ferrous metal specimens with a view to separating the effects of erosion from those of corrosion. Author finally discusses explanation of observed effects and puts forward the theory that the mechanism consists of severe repeated disturbance of the atoms in the metal lattice, resulting in increased opportunity for chemical reaction with water vapor and oxygen and also the development of local electrolytic cells due to the deformations. H. Kolsky, USA

176. Shalnev, K. K., Experimental study of the intensity of erosion due to cavitation, Pap. no. 22, 37 pp.

Author reports tests on cavitation erosion beyond circular profile model in rectangular water tunnel including graphs, sketches, and high-speed photographs of phenomena. Cavities originate on axis of vortex. In later stages, burbling cavitation zone becomes stationary. Intensive

erosion occurs at spot where cavity grows and breaks away from the damaged surface, not where it contracts. Thus initial stages of zone development show greatest erosion.

J. C. Geyer, USA

Incompressible Flow: Laminar; Viscous

(See also Revs. 26, 39, 149, 195, 214, 217, 218, 221, 226, 227, 230, 232, 238, 241, 243, 244, 245, 253, 255, 256, 257, 259, 260, 277, 278, 334, 336, 337, 351, 354, 357)

Book—177. Prandtl, L., A guide through fluid flow [Führer durch die Strömungslehre], 4th ed., Braunschweig, Freidr. Vieweg & Sohn, **1956**, xvi + 407 pp. DM 19.80.

Unaltered reprint of third edition (1948). As indicated by title, this book gives an introduction to the entire field of fluid dynamics. Treatment is very clear and succinct, using only a very moderate amount of mathematics. Physical and geometrical arguments are used in preference to analysis. Book is, therefore, an easily read, dependable source of information on a very large variety of phenomena. Only information on wind-tunnel technique and other experimental methods is very meagre. No attempt at all is made to bring text or references up to date.

L. J. F. Broer, Holland

178. Fadnis, B. S., Axisymmetric flow in perfect fluid, I, *Bull. Calcutta math. Soc.* **47**, 3, 143-152, Sept. 1955.

Paper presents stream functions for motion of a perfect fluid past a spheroid. Fluid is assumed to have a motion at infinity composed of a constant velocity and a uniform angular velocity with axis parallel to direction of uniform flow. Paper gives solutions for case where axis of spheroid is parallel to flow axis. Limiting case of flow past a disk is derived.

T. E. Caywood, USA

179. Campbell, I. J., The transverse potential flow past a body of revolution, *Quart. J. Mech. appl. Math.* **9**, part 2, 140-142, June 1956.

It is shown that in the potential flow of an incompressible inviscid fluid past a body of revolution set with its axis at right angles to the stream, the velocity components at the surface along and perpendicular to the meridians vary with azimuthal angle round the body in a simple manner. This is shown by entirely elementary considerations. From author's summary

180. Hasimoto, H., A sphere theorem on the Stokes equation for axisymmetric viscous flow, *J. phys. Soc. Japan* **11**, 7, 793-797, July 1956.

A theorem, analogous to Butler's theorem for an inviscid fluid, is given for finding the perturbation Stokes' stream function due to the insertion of a sphere ($r=a$) into an infinite viscous fluid which is in axisymmetric motion. The result is, of course, further limited in application to flows in which the resulting flow in the neighborhood of the sphere is "creeping" or Stokes' flow.

W. Daskin, USA

181. Kawaguti, M., On the viscous shear flow around a circular cylinder. II. Oseen's approximation, *J. phys. Soc. Japan* **11**, 5, 570-583, May 1956.

The shear flow (velocity gradient α) around a circular cylinder is studied by means of Oseen's approximate equations. A solution is sought in the form of a power series in α and the first two terms are obtained. Approximate formulas for lift and drag are derived. Author suggests that the solution may be useful in the case of a body submerged within a boundary layer or within a Poiseuille flow field. There is some doubt concerning the validity of the solution, since the resulting surface pressure is not single-valued in θ, θ being the angle in a polar coordinate system with origin at the cylinder's center.

[See also AMR **6**, Rev. 1954 for earlier paper by author on same subject.]

G. W. Morgan, USA

182. Sanyal, L., The flow of a viscous liquid in a circular tube under pressure-gradients varying exponentially with time, *Indian J. Phys.* **30**, 2, 57-61, Feb. 1956.

Author refers to investigations by Richardson and Tyler (1929) and by Sexl (1930) concerning periodically varying pressure gradient. They conclude that when the frequency-Reynolds number is large, the velocity distribution, instead of being parabolic, becomes of the boundary layer character. Reviewer may add that in Lamb's "Hydrodynamics," chap.XI, the limiting case of a single plane wall is explained.

Then, author analyzes the case of exponentially varying pressure gradient (both rising and falling with time) in a circular tube. Solutions are given in terms of Bessel functions. Reviewer notes that the same conclusions may also be obtained in the simpler case of two parallel walls, using circular instead of Bessel functions.

Author's conclusions are: (1) with (quickly enough) rising pressure gradient, the flow is of the boundary-layer type; (2) with (quickly enough) falling pressure gradient, an undulated velocity distribution appears *over the whole cross section of the tube.*

Reviewer believes these conclusions, especially the second one, may have a much more important meaning, e.g., in relation to the stability or instability of laminar flow, etc.

Also may be mentioned that the harmonically periodic and the exponentially varying pressure gradients are the only ones that do admit a temporary-constant, but a variable velocity distribution.

N. Krivoshein, Argentina

183. Sanyal, L., A note on Jeffery's exact solution of steady two-dimensional motion of a viscous liquid, *Bull. Calcutta math. Soc.* **47**, 3, 125-127, Sept. 1955.

Author recalculates Jeffery's solution of Navier-Stokes equations for which lines of equal vorticities are concentric circles [*Phil. Mag.* (6) **29**, 455-464, 1915], applying the more general method of Hamel [*Jahresber. Deutschen Math.-Vereinigung* **25**, 34-60, 1916].

H. Gortler, Germany

184. Golubev, V. V., Structure of the wake behind a poorly streamlined body (in Russian), *Izv. Akad. Nauk SSSR Otd. tekh. Nauk* no. 12, 19-37, Dec. 1954.

Paper goes rather thoroughly into the problem of the Karman vortex street type of wake. Though the reviewer is unable to cite a single unexpected result, the paper may be commended to those interested in this subject as an intelligent and thorough-going account. With this paper, as with other Russian articles that have crossed the reviewer's desk, the major portion of the work so closely parallels existing works that it is very hard to say where the contribution of the author begins. Consequently, a review reduces to a simple statement of the subject and the level of presentation.

R. A. Burton, USA

185. Dolidze, D. E., Unsteady motion of a viscous fluid created by a rotating disk (in Russian), *Prikl. Mat. Mekh.* **18**, 3, 371-378, 1954 (translated by M. D. Friedman, 572 California St., Newtonville, Mass., 10 pp.).

Karman's solution for uniformly rotating disk [cf. Goldstein, "Modern developments in fluid dynamics," sec. 43] is generalized to unsteady rotation started at zero time. Substitutions analogous to Karman's eliminate dependence on radius, leaving nonlinear parabolic partial differential equations depending on time and distance from plate. Linearized solution shows purely rotatory motion diffusing outward from plate; moment on plate is calculated. Iteration on linearized solution is shown to converge for sufficiently small time.

M. D. Van Dyke, USA

186. **Avalishvili, L. I., Fundamental solution of the linearized equations of the unsteady motion of a viscous fluid** (in Russian), *Soobshch. Akad. Nauk Gruzin. SSR* **12**, 7, 397–401, 1951 (translated by M. D. Friedman, 572 California St., Newtonville, Mass., 5 pp.).

The fundamental solution of the linearized equations is constructed and shown to satisfy the imposed initial and boundary conditions.

A. H. Sacks, USA

187. **Eckhaus, W., The induced drag due to disturbances in the lift distribution,** *Nat. LuchtLab. Amsterdam Rap.* F. 154, 12 pp. + 14 figs., 1954.

An approximative method is presented by which the increase in induced drag caused by a disturbance in the lift distribution, for some frequently occurring types of disturbances, can be rapidly calculated from figures given in the report.

From author's summary by J. R. Spreiter, USA

188. **Taylor, G. I., and Miller, J. C. P., Fluid flow between porous rollers,** *Quart. J. Mech. appl. Math.* **9**, part 2, 129–135, June 1956.

When a viscous fluid is entrained between two rollers which are separated by a small distance, a pressure is developed on the upstream side of the point of nearest approach and a suction on the downstream side. Theoretically these both become infinite when the rollers are in contact. These infinities are avoided when the rollers are slightly porous, and this situation is analyzed by the authors who compute the pressure distribution. Results may have industrial applications to paper-making machines and to rollers used for painting walls.

From authors' summary by A. E. Green, England

189. **Becker, E., Contributions to the study of secondary flow** (in German), *Mitt. Max-Planck-Inst. Stromungsforschung* 13, 85 pp., 1956.

A discussion is given of theoretical and experimental work done by others (mainly German and British workers) on secondary flows in pipes, ducts, and cascades. The analytical part consists of investigations of incompressible laminar pipe flow, laminar channel flow, and turbulent channel flow, so that solutions (iterative solutions using series expansion) may be obtained. The main part of the analysis (channel flows) is restricted to axially symmetric flows in shallow channels with large radius of curvature. The secondary flows are then in the radial direction only. It is of interest to note that the Prandtl mixing-length theory is used for the turbulent shear instead of more modern concepts. Experimental verification for turbulent flows in two channels of different sizes is fair considering that, especially in the smaller channel, rotational symmetry has not been achieved. An appendix discusses the measurements with a two-hole cylindrical probe.

T. P. Torda, USA

190. **Hagerty, W. W., and Shea, J. F., A study of the stability of plane fluid sheets,** *J. appl. Mech.* **22**, 4, 509–514, Dec. 1955.

The fluid sheet issuing from a nozzle can develop spray as a result of ripples or waves that destabilize the sheet. If the frequency and wave length of these waves were known, it might shed light on the size and spatial distributions of the drops in the spray. A stability problem which the authors were able to solve is that of a plane sheet of fluid flowing through another fluid of different density with surface tension at the interfaces. The solution was obtained by assuming that the parallel sides of the sheet are vibrating sinusoidally about their equilibrium position and then applying a stability analysis using classical hydrodynami velocity potentials. A boundary condition at the interfaces involving both pressures and surface tension is satisfied. It is shown that two types of waves can exist, sinuous waves in which both sides of the sheet oscillate in phase, and dilation waves in which they oscillate out of phase. For all frequencies less than a given frequency, depending among other things on sheet velocity, both types of waves are amplified, but the sinuous waves are amplified more strongly than the dilation waves.

Experimental measurements were made with a nozzle producing plane sheets of water to determine the wave structure and the growth rates (amplification) of waves introduced into the sheet at the nozzle. The sinuous waves dominated the sheet, and the experimental growth rates agreed very well with the theoretical rates for sinuous waves. However, some of the photographs of the waves make the reviewer wonder how accurately the growth rate can really be determined. Some discussion of this point should have been included. The authors are unable to account for apparently self-induced waves that were not deliberately introduced into the sheet at the nozzle.

J. N. Nielsen, USA

191. **Broer, L. J. F., On the theory of the ventilation of traffic tunnels,** *Appl. sci. Res.* (A) **6**, 1, 29–44, 1956.

The equations, expressing conservation of mass, for the flow of air and for the concentration of contaminants (C) (such as carbon monoxide and smoke) in a ventilated traffic tunnel are set up. Mathematical method consists mainly in solving a linear partial differential equation for C as a function of time and distance along the tunnel. Characteristics of the equation are used for analysis of the solution. The two most promising types of ventilation systems are compared, with numerical examples. A ventilating system in which air is blown into and out of the tunnel by means of ventilation ducts alongside the tunnel seems especially advantageous according to the analysis.

M. Morduchow, USA

192. **Heinrich, H. G., Drag and stability of parachutes,** *Aero. Engng. Rev.* **15**, 6, 73–81, June 1956.

The common types of parachutes are briefly described and illustrated, and the relationship between the effective drag of a parachute and its stability is explored.

From author's summary

193. **Watt, D. A., Electromagnetic pumps for liquid metals,** *Engineering* **181**, 4703, 264–268, Apr. 1956.

The use of liquid metals as reactor coolants or as solvents for reactor fuels calls for a convenient and reliable means of pumping these highly radioactive and sometimes costly materials. The electromagnetic pump, which employs neither seals nor moving parts, seems the ideal solution to the problem, and in this article the more useful examples are briefly described. Author examines the elementary considerations affecting the design and application of compensated direct-current and travelling-field alternating-current pumps, which he regards as the most important versions, and gives a short over-all survey of the electromagnetic pumping equipment developed by the United Kingdom Atomic Energy Authority. Article is based on lectures given at the Atomic Energy Reactor School, Harwell. (Some introductory remarks concerning liquid-metal pumps and details of pumps made by a private company are given on page 281.)

From author's summary

Compressible Flow, Gas Dynamics

(See also Revs. 229, 233, 234, 235, 239, 251, 253, 265, 268, 271, 273, 274, 296)

194. **Alford, W. J., Jr., Theoretical and experimental investigation of the subsonic-flow fields beneath swept and unswept wings, with tables of vortex-induced velocities,** *NACA TN* 3738, 91 pp., Aug. 1956.

Flow field around swept wing is determined theoretically, assuming inviscid potential flow. The problem is separated into two

parts: (1) determination of induced velocities at zero lift, and (2) determination of lift-induced velocities. The velocities at zero lift are found by using results of Neumark [AMR **6**, Rev. 1691; **7**, Rev. 1864], the chordwise section of the wing being taken as part of a swept wing of infinite span. This is valid for sections not too close to the wing root or tip. The lift-induced velocities are found by lifting-surface theory, using 40 horseshoe vortexes. It is shown that the sidewash velocity obtained in this manner must be corrected to give a more accurate variation of sidewash for small distances from the wing chord plane. Full details of the theory are given in appendixes, and the perturbation velocities induced by a unit horseshoe vortex are tabulated. The effects of compressibility are allowed for, using a modified Prandtl-Glauert formula.

Theory is compared with experimental results for two wings (and fuselage); one swept, one unswept. Both theory and experiment show existence of significant chordwise gradients in the flow characteristics. These gradients become smaller as the distance from the wing chord plane is increased. Increasing the lift coefficient causes large changes in the local downwash and sidewash angles and in the dynamic pressure.

In general, there was good agreement between theory and experiment up to the incidence causing separation at the chordwise section considered. The magnitude of the downwash tended to be overestimated as the tip of the swept wing was approached; sidewash ahead of the unswept wing was underestimated.

A. W. Babister, Scotland

195. Owczarek, J. A., Theoretical investigation of the influence of viscous friction on a plane wave of finite amplitude in a compressible fluid, *Quart. J. Mech. appl. Math.* **9**, part 2, 143–163, June 1956.

The theory of small-amplitude, plane waves traveling through a viscous gas at subsonic speeds is extended. Reflections and interactions are not considered. Viscous friction is assumed proportional to dynamic pressure and then equations suitable for point-to-point solutions are developed using the method of characteristics. Further equations which can be numerically integrated are derived for the case of very weak waves. Friction is found to decrease both pressure and temperature following a weak compression wave, to increase the pressure and temperature in a weak rarefaction, and to decrease the gas velocity.

C. F. Hansen, USA

196. Anderson, R. F., Notes on the calculation of the subsonic downwash and sidewash angles near wings, *J. aero. Sci.* **23,** 7, 707–708 (Readers' Forum), July 1956.

197. Owczarek, J. A., Measurements of attenuation of compression waves of finite amplitude in air and evaluation of the coefficient of friction, *Quart. J. Mech. appl. Math.* **9**, part 2, 164–184, June 1956.

The effect of viscous friction on subsonic compression waves of small amplitude is measured. These waves are produced in a tube by an accelerating piston, and pressures are measured as a function of time and of distance from the source. The pressures generated are found smaller than isentropic wave pressures. The pressure changes are used to calculate friction coefficients as a function of Reynolds number based on flow length.

C. F. Hansen, USA

198. Miles, J. W., On linearized transonic flow theory for slender bodies, *J. aero. Sci.* **23**, 7, 704–705 (Readers' Forum), July 1956.

Book—199. Hermann, R., Supersonic inlet diffusers and introduction to internal aerodynamics, Minneapolis, Minn., Minneapolis-Honeywell Regulator Co., 1956, xxi + 378 pp.

In this book Dr. Rudolf Hermann has given a systematic and comprehensive study of supersonic inlet diffusers and the control problems associated with such devices. The basic fundamentals of one-dimensional, two-dimensional, and axisymmetric diffusers are presented in a clear fashion. Wherever possible the results of theoretical studies are substantiated by experimental data. The text is appropriately illustrated with numerous schematics, graphs, and photographs in addition to a large amount of tabulated data. The comprehensive list of pertinent references given at the end of this book makes it a valuable addition to the library of investigators engaged in this specific field of research.

The chapters of the book are as follows: Chap. 1. Various diffuser types, their functions and applications in supersonic aerodynamics. Chap. 2. Diffuser with the normal shock in front: Flow process, efficiency and the starting or swallowing process in one-dimensional analysis. Chap. 3. Diffuser with the normal shock swallowed: Flow process and efficiency in one-dimensional analysis.

Chap. 4. The two-dimensional symmetric multiple shock diffuser with a wedge of constant angle installed in a duct. Chap. 5. The two-dimensional multiple shock inlet diffuser with equal upper and lower wedge angles. Chap. 6. Analysis of a two-dimensional multiple shock system for optimum pressure recovery. Chap. 7. Comparative evaluation of two-dimensional unsymmetric multiple shock inlet diffusers composed of wedges with unequal or angular steps.

Chap. 8. The axially symmetric spike inlet diffuser—basic analysis of on-design Mach number operation. Chap. 9. The axially symmetric spike inlet diffuser—experimental data and comparison with analysis.

In the final section are an appendix of numerical tables, references, terminology, and an index.

J. Persh, USA

200. Pack, D. C., The oscillations of a supersonic gas jet embedded in a supersonic stream, *J. aero. Sci.* **23**, 8, 747–753, 764, Aug. 1956.

The interaction of aligned, unidirectional streams such as occurs aft of rockets in supersonic flight is examined for both two-dimensional and axially symmetric jets. Laplace transform methods are applied to obtain solutions for the perturbation velocity potentials of the inviscid, linearized equations of motion. Confirmation of earlier two-dimensional results (e.g., Pai) is obtained for the relative stream Mach numbers for which the jet boundary either oscillates or monotonically approaches an asymptotic value. The asymptotic change in width for the axially symmetric jet is shown to be 1/2 that of the two-dimensional jet. Only the behavior at large and small distances from the exhaust plane are considered for the circular jet, from which it is concluded that the asymptotic width is approached rapidly.

J. R. Baron, USA

201. Kogan, A., On inviscid flow near an airfoil leading edge or an ogive tip at high supersonic Mach numbers, *J. aero. Sci.* **23**, 8, 794–795 (Readers' Forum), Aug. 1956.

202. Cheng, H. K., and Pallone, A. S., Inviscid leading-edge effect in hypersonic flow, *J. aero. Sci.* **23,** 7, 700–702 (Readers' Forum), July 1956.

203. Mahony, J. J., and Meyer, R. E., Analytical treatment of two-dimensional supersonic flow. I. Shock-free flow, *Phil. Trans. roy. Soc. Lond.* (*A*) **248,** 952, 467–498, Feb. 1956.

The two-dimensional equations of motion for a homentropic irrotational steady supersonic gas stream are transformed to a pair of new equations in which singularities such as limit lines can be handled more easily. It is shown how an iteration procedure using Riemann functions or a double power series may be used to integrate them. The first method is used to calculate the pressure distribution in the first interaction region of a jet expanding from a perfect nozzle, and the second method is used to show that shock

waves will always occur in the first period even for pressure ratios arbitrarily near unity. The methods are also shown to be suitable for the calculation of flow past airfoils of arbitrary shape but no examples are worked out in detail.

K. Stewartson, England

204. Mahony, J. J., Analytical treatment of two-dimensional supersonic flow. II. Flow with weak shocks, *Phil. Trans. roy. Soc. Lond.* (*A*) **248**, 952, 499–515, Feb. 1956.

The methods given in part I (see preceding review) are applied to problems in which the shocks which occur are so weak that the flow behind them is practically homentropic. It is shown that then the whole flow may be determined without reference to the particular shock shapes. A method is given by which the positions of the shocks may be determined from the solution in the characteristic plane. Examples, none of them numerical, are given illustrating three possible types of singularity from which a shock may start, including a discussion of the expanding supersonic jet. Finally, the effect of entropy variations on the accuracy of the solution is considered.

K. Stewartson, England

205. Rao, P. S., Supersonic bangs. Part I, *Aero. Quart.* **7**, 1, 21–44, Feb. 1956.

A nonlinear theory of the supersonic bangs from an accelerating body is worked out, using an extension of Whitham's method. The strength of the bow shock is determined, and it is shown that the effect of acceleration on the pressure rise is appreciable at large distances from the nose for Mach numbers near unity. Results are compared with those of linear theory; the estimate for the pressure rise is found to be about half the linear value. Results also include an expression for the curvature of an attached shock at the nose, and a formula for the decay of a shock after it is detached from a decelerating body.

From author's summary

206. Carafoli, E., and Ionescu, M., Supersonic drag of double-conical delta wings with variable slope (in French), *Acad. Repub. pop. Rom. Rev. Mecan. appl.* **1**, 1, 35–55, 1956.

The wings considered are constructed by taking the difference between two cones having a common base but different heights. The base shapes are defined by assuming a linear spanwise variation of the slope of streamwise sections. Linear theory is used to compute the wave drag. The Mach number range considered includes subsonic ridge lines and supersonic leading edges.

G. E. Nitzberg, USA

207. Carafoli, E., and Horovitz, B., Supersonic flow around an airfoil with axial fins (in French), *Acad. Repub. pop. Rom. Rev. Mecan. appl.* **1**, 1, 7–33, 1956.

Busemann's method of conical supersonic flow is applied to delta wings with two axial conical fins. The plane of the fins is supposed to be perpendicular to the wing. The following cases are dealt with in detail: Delta wings with polygonal cross section and symmetrical double wedge delta wings, the fins being aligned either at zero angle or at a small nonvanishing angle. In usual manner, the problem is reduced to find an analytic function in the interior of the Mach circle of the conical field satisfying the boundary conditions given along the Mach circle and on the surfaces of the wing and the fins. There are several subcases, as the leading edges of the wing may be subsonic or supersonic.

Finally, some applications are discussed: rectangular wings with fins on the right and the left wing side, and cross-formed conical wings attached antisymmetrically. Formulas are given for drag, lift and rolling moment.

R. Sauer, Germany

208. Graham, M. E., Application of drag-reduction methods to supersonic biplanes, *Douglas Aircr. Co. Rep.* SM-19258, 74 pp., Sept. 1955.

A study is made by linearized theory of the pressure drag reduction of supersonic biplanes with a basic configuration of a Sears-Haack fuselage with two symmetrically located elliptic planform wings. The drag of singularity distributions is considered. It is shown that, by carrying a lift distribution on the fuselage or by reshaping the fuselage and carrying more lift on the upper wing than on the lower wing, the drag can be reduced on the order of 15% or 25%, respectively.

H. G. Lew, USA

209. Ipsen, D. C., Experiments on cone drag in a rarefied air flow, 1955 Heat Transfer and Fluid Mech. Inst., Los Angeles, Univ. of Calif., June 23–25, 1955. Pap. 10, 6 pp.

Interesting experiments on drag on fore portion of circular cone in rarefied flow at Re 70 to 5000 and $M = 2$ to 4 show (1) greater drag than would be predicted by first-order boundary-layer analysis, (2) second-order shear correction due to transverse curvature gives fairly good agreement with tests, (3) slip does not appear to exert strong influence, although some deviations between theory and experiment may be due to slip.

M. Z. Krzywoblocki, USA

210. Graham, E. W., The drag of superimposed optimum lift distributions in supersonic flow, *Douglas Aircr. Co. Rep.* SM-18839, 19 pp., Apr. 1955.

Linearized theory is used for theoretical evaluation of supersonic aircraft wave and vortex drag. The method consists of representing the aircraft by a model of several superimposed known elementary lift distributions. The optimum conditions under which interference drag may be computed are shown.

H. H. Hilton, USA

211. Sohngen, H., Flow upstream of supersonic axial compressor composed of one rotor (in German), *Dtsch. Versuch. Luftfahrt E. V. Rep.* 11, 23 pp., Dec. 1955.

The flow through an axial compressor consisting only of one rotor is investigated in the case of subsonic axial but supersonic rotation velocity of the blades. The flow field of the simplified two-dimensional model is composed of the undisturbed constant velocity, the disturbances by the grid, and their reflections at the entrance section. In the region behind the rotor the flow is strongly nonhomogeneous and subject to losses, but it seems possible to homogenize the flow field by using appropriate triangular profiles.

W. Wuest, Germany

212. Kendall, J. M., Jr., Experimental investigation of leading edge shock wave-boundary layer interaction at hypersonic speeds, *Cal. Inst. Technol. Guggenheim Aero. Lab.* no. 385, 24 pp. + 14 figs., Jan. 1956.

The boundary layer on a slender body tends to be very thick at hypersonic speeds. It interacts with the external flow by producing larger flow deflections near the leading edge than those due to the body alone. The increased shock strength affects the boundary-layer growth. The flow around the boundary layer gives rise to an induced pressure with a negative gradient which thins the boundary layer and increases the skin friction with respect to the zero pressure gradient value.

Experiments on a flat plate with a sharp leading edge ($Re_t <$ 100) have been performed in the GALCIT 5 × 5-in. Mach 5.8 hypersonic wind tunnel. The induced pressure was measured by means of orifices in the plate surface. Profiles of Mach number, velocity, mass flow, pressure, and momentum deficiency were calculated from impact pressure surveys normal to the plate surface made at various distances from the leading edge.

The results are as follows: (1) The induced pressures are 25% higher than the weak interaction theory. (2) The boundary layer and the external flow are distinctly separate for Re_x as low as 6000. (3) Expansion waves reflected from the shock are weak. (4) The average skin-friction coefficient tends toward and nearly matches the zero pressure gradient value downstream, but in-

creases to approximately twice that value as the leading edge is approached. From author's summary

213. Schwartz, R. N., and Eckerman, J., Shock location in front of a sphere as a measure of real gas effects, *J. appl. Phys.* **27,** 2, 169–174, Feb. 1956.

Spheres were fired at supersonic speeds into monatomic gases and into chlorine gas. The position of the shock wave which forms in front of the sphere depends on the Mach number and gas state before and after crossing the shock wave. Measurements of position made in monatomic gases agree fairly well with aerodynamic theory. As the shock position depends on the actual gas state attained, and thus molecular excitation times, measurements in more complicated gases than a monatomic gas can give information as to amount and rates of excitation. The vibrational energy excitation in chlorine was singled out for study. This excitation involves a well-known rate process. By carrying out shock position measurements at several different pressures, it is possible to infer the order of magnitude of the vibrational relaxation time in chlorine; the present results are in agreement with shock tube measurements of the relaxation time.

From authors' summary

214. Verschaffelt, J. E., Relative flow of a fluid (in French), *J. Phys. Radium* **17,** 4, 313–319, Apr. 1956.

Two systems of coordinates are considered: one fixed, the other with each point moving with velocity v with respect to the other. Assuming that $(\partial(a)/\partial t)' = \partial a/\partial t + v.\ \text{grad}\ a$, and $(\partial(ca)/\partial t)' = \partial(ca)/\partial t + \text{div}\ (cav)$ (where the primes denote the differentiation in the moving system, a an arbitrary variable, and c the mass per unit volume), some equations of fluid flow given in the fixed system are expressed in the moving system. It is found, for example, that the continuity equation is the same only if div v = 0. Also, it is found that a Coriolis acceleration and centrifugal acceleration appear in the momentum equation when the relative system simply rotates with respect to the fixed system.

H. P. Eichenberger, USA

215. Pengelley, C. D., Flow in a viscous vortex, Southwest Res. Inst. Rep. 494C-1, 59 pp., Mar. 1956.

This report presents the results of an analytical investigation of flow in a two-dimensional viscous vortex based on the assumption of a steady-state component of radial flow. Equations are developed from the first law of thermodynamics, the general Navier-Stokes equation, and the ideal-gas laws. Selecting a reference radius where the viscous stress is zero dimensionless, relations are developed and presented in the form of generalized charts for convenience in application. Although the results are valid for laminar flow, only some possible applications in turbulent flow are discussed. J. F. Lee, USA

216. Ostrach, S., and Moore, F. K., Effect of transverse body force on channel flow with small heat addition, *NACA TN* 3594, 31 pp., Feb. 1956.

Steady, compressible, inviscid channel flow to which heat is added at a cross-sectional plane and which is also subject to a transverse body force is analyzed. Parameters governing the flow are a dimensionless heat parameter and Mach and Froude numbers. Solutions which are qualitatively similar are obtained for cases in which either Mach number is small or Froude number large. If heat is added uniformly over the plane, streamlines are displaced in the direction of the body force, and downstream of the heat addition the flow is found to be a shear flow. If heat addition is concentrated near the center of the cross-sectional plane, a strong vortex motion appears downstream in addition to the shear flow.

In the first part of the analysis, the through-flow Mach number is considered small. Subsequently, the alternate assumption of large Froude number is made. For large Froude numbers it is found that an increase in Mach number to unity increases the magnitude of the body-force effects. The configuration studies can be considered to be an idealization of the flow in a ram jet mounted at the tip of a whirling helicopter rotor blade. Effects of the transverse body force are important in this example. Actually, even if the Froude number is large, the vortex motion due to any nonuniformity of heat addition may be quite vigorous.

From authors' summary by F. O. Woodsome, USA

217. Korobeinikov, B. P., On the integral equations of unsteady adiabatic gas motion (in Russian), *Dokladī Akad. Nauk SSSR (N.S.)* **104,** 4, 509–512, 1956 (translated from Russian by M. D. Friedman, 572 California St., Newtonville, Mass., 6 pp.).

Method of Lidov [title source **103,** no. 1, 1955], based on dimensional analysis, is used to find integral equations of certain one-dimensional isentropic flows. Earlier results for perfect gas are extended to cover any equation of state and cases where flow is not self-similar in time. W. Griffith, USA

218. Lavender, R. E., Application of Kelly's theory to cone-cylinder-frustum bodies of revolution, *J. aero. Sci.* **22,** 9, 654–655 (Readers' Forum), Sept. 1955.

H. R. Kelly in "The estimation of normal force and pitching moment coefficients for blunt-based bodies of revolution at large angles of attack," *NOTS Tech. Memo* 998 (1953), improved the theory of viscous crossflow over cone-cylinder and ogive-cylinder for cases of all laminar or all turbulent axial flow. Normal force and pitching moment variation with angle of attack in both subsonic and supersonic flow predicted by his theory gave good agreement with experiment. The theory assumes that the axial distribution of the crossflow drag for inclined bodies is similar to the drag for a circular cylinder moving crosswise in a fluid when started impulsively from rest and that the crossflow drag coefficient depends upon whether or not the axial flow is laminar or turbulent.

The author of this note extends Kelly's theory to cone-cylinder-frustrum bodies and not only for all laminar or all turbulent axial flow, but also when the flow is in transition near the cone-cylinder juncture, or near the cylinder-frustrum juncture. He derives for his case the additional normal force and pitching moment due to crossflow. The experimental agreement is not mentioned.

T. Leser, USA

Wave Motion in Fluids

(See Revs. 195, 197, 354).

Turbulence, Boundary Layer, etc.

(See also Revs. 185, 212, 256, 287, 288, 290, 292, 297, 298, 299, 316, 340, 341)

219. Stewart, R. W., A new look at the Reynolds' stresses, *Canad. J. Phys.* **34,** 7, 722–725 (Note Section), July 1956.

Having been stimulated by A. A. Townsend's recent monograph, "The structure of turbulent shear flow", author makes explicit that the traditional eddy viscosity concept for the Reynolds stresses in usual "mixing length" form is misleading and the physical picture it invokes is inaccurate. He shows that (1) it is preferable to regard the Reynolds stresses as pressures, and they are only important in that they express the amount and orientation of the anisotropy of the turbulence; and (2) the scale of the

turbulence is of no consequence as far as its effects on the mean flow are concerned. S. Tomotika, Japan

220. **Lin, C. C., Aspects of the problem of turbulent motion,** *J. aero. Sci.* **23**, 5, 453–461, 516, May 1956.

General characteristics of turbulent motion and important features of transition from laminar to turbulent flow are described. Statistical approach to the problem of turbulent motion is discussed. Cardinal points of various approximate theories are examined and some of the predictions are compared with experiments. It is a good survey of the field. M. S. Uberoi, USA

221. **Munk, M. M., On the supremacy of viscosity in the control of turbulent fluid motion,** Catholic Univ. of America, Dept. of Aero. Engng. 23 pp., Apr. 1956.

This obscurely written paper appears to be based on the claim that viscous forces affect the statistical properties of turbulent motion a good deal more than inertia and pressure forces, even when the Reynolds number is not small. This claim, which is the opposite of what is generally believed, was made once before for the special case of isotropic turbulence [*J. aero. Sci.* **4,** p. 131, 1937] and disproved for that same case [*J. aero Sci.* **4,** p. 311, 1937 and *Proc. roy. Soc.* (*A*) **164,** p. 15, 1948].

G. K. Batchelor, England

222. **Fleishman, B. A., Dispersion of mass by molecular and turbulent diffusion: one-dimensional case,** *Quart. appl. Math.* **14,** 2, 145–152, July 1956.

Author considers the equation governing one-dimensional molecular diffusion in the presence of a convection velocity

$$\partial\sigma/\partial\xi - \partial^2\sigma/\partial\tau^2 = -\Omega[\partial(\sigma\omega)/\partial\xi] \qquad [1]$$

where all the quantities are dimensionless: τ, ξ being the time and space coordinates, $\sigma(\xi, \tau)$ the concentration of dispersing matter, $\omega(\xi, \tau)$ the convective velocity, and Ω a constant. First a method is developed expressing the concentration as a power series in Ω:

$$\sigma(\xi, \tau) = \Sigma\, \Omega^i \sigma_i(\xi, \tau)$$

the solution of [1] in $\{-\infty < \xi < +\infty,\ 0 \leqslant \tau \leqslant \tau_0\}$ corresponding to given initial condition $\sigma(\xi, 0) = \varphi(\xi)$. Sufficient condition for uniform convergence of the series and its physical interpretation is stated.

In the second part, author assumes that the velocity $\omega(\xi, \tau)$ is a random function, with zero mean value and variance independent of (ξ, τ); he proves that mean value of $\sigma_1 = 0$ and computes the mean value of σ_2 in terms of the correlation coefficient of ω; similarly the mean value of σ_n involves the nth-order correlation coefficient of ω. The case of initial distribution of Gaussian type is considered in a numerical example.

J. Kampe de Feriet, France

223. **Quick, A. W., A method for investigating exchange phenomena in turbulent flow downstream of bodies with separated flow** (in German), *Dtsch. Versuch. Luftfahrt E. V. Rep.* 12, 34 pp., Mar. 1956.

The exchange of gases between the detached flow region and the undisturbed gas stream behind bodies with a blunt base is an important parameter in many applications of fluid dynamics. Particularly, questions concerning the mixing of air and fuel in combustion chambers (mixing quality, burner flame-out, etc.) are closely related to the mechanism of mixing. Theoretical considerations by the author revealed that it suffices to measure the decrease of concentration of a substance introduced into the vortex behind the body as a function of time and the size of the vortex to obtain information about important mixing parameters such as the time for which the air remains in the vortex and the number of circulations it performs during this time, and an exchang factor that is defined as the ratio between the amount of air entering the vortex and the amount of air in the vortex.

The experiments reported were conducted behind an axisymmetric blunt-based body. Axisymmetric bodies have the advantage of forming a stable annular vortex, contrary to two-dimensional bodies that form vortex streets which are not suitable for the method described. Smoke was used as the substance to be introduced into the vortex. Its concentration was measured by means of a light beam that penetrated the vortex and fell on a photo cell. A static calibration provided the relation between smoke concentration and photo-cell current.

In order to check the results, a relation was developed between the drag of the body and the amount of air entering the vortex per second. A satisfactory agreement was obtained.

It is pointed out that tests with hot combustion gases will have to be conducted in order to show reliability of method for combustion problems. In those tests, smoke can be replaced by chemicals that produce conspicuous colors.

Reviewer believes that method has great merit and should be suitable for a large number of basic tests on the mixing of air and fuel in combustion engines and for similar problems.

H. J. Ramm, USA

224. **Charwat, A. F., The decay of turbulence near the critical Reynolds number,** *J. aero. Sci.* **23,** 8, 799–800 (Readers' Forum), Aug. 1956.

225. **Cooper, R. D., and Lutzky, M., Exploratory investigation of the turbulent wakes behind bluff bodies,** *David W. Taylor Mod. Basin Rep.* 963, 31 pp., Oct. 1955.

The mean velocity and the turbulence intensity of the axial component of the fluctuating velocity were measured in the wakes behind a disk and a series of four rectangular plates. For axially symmetric wakes, in agreement with theoretical results derived from similarity considerations, it was found that: (1) The maximum values of the mean velocity defect U_d and the turbulence intensity u' vary inversely as $x^{2/3}$, where x denotes the axial position in the wake; (2) the radius of the wake varies as $x^{1/3}$; (3) transverse distributions of U_d and u' are universal functions of $\eta = r/x^{1/3}$, where r denotes the radial position in the wake.

The microscale of turbulence λ was found experimentally to vary as $x^{1/4}$, in contrast to the $x^{1/2}$ variation theoretically predicted from similarity considerations. From authors' summary

226. **Eichelbrenner, E. A., and Werle, H., Separation in two-dimensional laminar flow: Comparison of theory and experiment** (in French), *Rech. aéro.* no. 51, 11–18, May/June 1956.

For flow past a laminar wing (NACA 64-A-015) in a water tunnel, comparisons between observation and the Pohlhausen theory have been made for the point of separation and for the distributions of velocity in the boundary layer nearby. Good correspondence is found for the point of separation. Velocity profiles do not correspond as well, and the observed separation zone is slightly thicker than that predicted. Prandtl's hypothesis ceases to be valid in this region because of pronounced pressure gradient and flow normal to the boundary. J. S. McNown, USA

227. **Sanyal, L., Two-dimensional boundary-layer flow along a wall in a converging channel with curved boundaries,** *Bull. Calcutta math. Soc.* **47,** 3, 129–133, Sept. 1955.

Paper considers the laminar incompressible flow in a converging channel with two circular boundaries (or one circular one and a straight one) which, when produced, are tangent to each other at the point of contact. The flow in the center of the channel is taken to be the appropriate inviscid irrotational flow for this configuration. The boundary-layer flow along the walls is calculated from

the boundary-layer equations by the Pohlhausen momentum integral method. Numerical results for the variation of the boundary-layer thickness along a wall are presented for one special case.

D. W. Dunn, USA

228. Hurley, D. G., The downstream effect of a local thickening of the laminar boundary layer, *Aero. Res. Labs. Melbourne, Austral. ARL/A Note* 146, 5 pp. + 2 figs., July 1955.

A simple approximate method of calculating the downstream effect of a local thickening of a laminar boundary layer is given. It is shown that the thickening dies away very rapidly in a favorable pressure gradient, but is magnified by an adverse pressure gradient. This confirms a conclusion that was drawn from experiments on the effects of surface roughness on the stalling characteristics of a thin wing.

From author's summary

229. Mirels, H., Boundary layer behind shock or thin expansion wave moving into stationary fluid, *NACA TN* 3712, 53 pp., May 1956.

Study covers laminar and turbulent boundary layers behind compression or expansion waves propagating along a flat wall. Solutions were obtained by introducing usual boundary-layer assumption and by using numerical integration. Results for several wave strengths are tabulated.

It is pointed out that, for strong shock, there exists a large normal temperature gradient near the wall, so a reevaluation of ordinary laminar boundary-layer assumption will be necessary; for very strong shock, the flow behind usually dissociates.

H. S. Tan, USA

230. Ito, H., On the pressure losses for turbulent flow in smooth pipe bends, *Rep. Inst. high Speed Mech., Tohoku Univ.* (*B*) 6, 55–102, 1956.

It is deduced from momentum integral equations that the loss coefficients for turbulent flow in smooth pipe bends is a function of $Re\ (a/R)^2$ and $\theta\ (R/a)^{1/2}$ where Re is the Reynolds number, a the radius of the pipe, R radius of the bend, and θ angle of the bend. It is shown experimentally that these are the significant parameters as long as the radius of the bend is at least ten times that of the tube.

A. M. Kuethe, USA

231. Moore, F. K., Three-dimensional boundary layer theory, pp. 159–228, Advances in Applied Mechanics, Vol. IV (Dryden, H. L., von Karman, T., and Kuerti, G., editors), New York, Academic Press, Inc., 1956.

This is a comprehensive and useful survey of recent developments in three-dimensional boundary-layer theory.

Author considers in turn the boundary layers on rotating bodies, surfaces of revolution in axial motion, and yawed infinite cylinders. Finally, he deals with the more general problems of boundary-layer separation, boundary regions, and laminar stability.

Seventy nine references are listed.

A. R. Mitchell, Scotland

232. Zaat, J. A., Spiegel, E. V., and Timman, R., The three-dimensional laminar boundary-layer flow about a yawed ellipsoid at zero incidence, *Nat. LuchtLab. Amsterdam Rap.* 165, 16 pp., Jan. 1955.

Flow field around an ellipsoid with axis ratios 3, 1, 0.15, yawed at 45° to a uniform flow, is solved. Method of Timman (reviewed briefly in paper) is used to solve laminar boundary-layer equations. Potential flow about body is first derived and momentum equations in streamline direction and perpendicular to this direction derived. These can be reduced to a set of quasi-linear first-order partial differential equations. Equations are solved by numerical methods and all basic functions are tabulated in paper. Graphs illustrate quantities of main interest up to separation condition. Paper is aimed at explaining flow along sweptback wing.

W. D. Baines, Canada

233. Chuan, R. L., On the supersonic flow of a viscous fluid over a compression corner, 1956 Heat Transfer and Fluid Mechanics Institute, Stanford, Cal., Prepr. no. 12, 19 pp.

The nature of a compressible boundary layer interacting strongly with an external isentropic flow compressed by a corner is investigated experimentally for the case Mach number 2.54, Reynolds number 600,000/inch. Detailed measurements of wall pressure and pitot pressure distributions through boundary layer were taken for case of boundary layer turbulent throughout, and for transitional case—layer enters interaction region laminar but leaves turbulent. Wall pressures and schlierens only were taken for completely laminar case.

Relationships (similar to that predicted by Lees-Crocco theory) between mean temperature and mean velocity in the boundary layer have been found to exist throughout interaction zone; one for turbulent case and two for transitional case representing, respectively, laminar separating and turbulent reattaching flow. Experimental determination of mixing rate for transitional and turbulent cases— indicating momentum transport from free-stream (by mass entrainment) to low-speed portion of boundary layer—indicates high dependence on (momentum thickness) Reynolds number.

J. S. Isenberg, USA

234. Walz, A., A new approximative method for the calculation of laminar and turbulent boundary layers in compressible flow (in French), *Publ. sci. tech. Min. Air, France 309, 87 pp., 1956.*

Paper is an attempt to evaluate boundary-layer parameters at high Mach numbers (up to $M=12$) by numerical integration of the equations of continuity, momentum, and energy. A one-parameter velocity profile is postulated, with Prandtl number of unity and no heat transfer. Empirical laws for the wall shear stress of an incompressible boundary layer are adapted for the compressible case, and used in the integrations. Results are presented graphically, in terms of familiar parameters, for the flat plate and for selected bodies of revolution. These are intended to be used for general calculations. Comparison with experiments is good in view of the simplifications. The use of the equations for the balance of turbulent energy is novel with respect to compressible boundary layers, and is important.

R. Stevenson, USA

235. De Coursin, D. G., An experimental study of the effect of small angles of attack on the laminar boundary layer of a cone, *Univ. Minn. Inst. Technol. Rosemount Aero. Lab. Res. Rep.* 121, 40 pp. + 26 figs., Aug. 1955.

Total head traverses at a single station on a 15° cone at Mach number 2.7 have been used to determine the effect of yaw on laminar boundary-layer velocity profiles and skin friction. Angle of attack ranged from 0 to 4°.

Skin-friction coefficient at zero angle of attack was appreciably less than predicted by either flat-plate theory adapted to cone flow, or Moore's plane-of-symmetry theory. With increasing incidence, the increment in skin friction on the windward side agreed well with Moore's theory. On the leeward side, the boundary layer was nonlaminar and complicated by crossflow.

Accuracy of measurements was limited by nonuniformity in test section flow and possibly by pitot-tube interference.

D. C. Collis, Australia

236. Sommer, S. C., and Short, B. J., Free-flight measurements of skin friction of turbulent boundary layers with high rates of heat

transfer at high supersonic speeds, *J. aero. Sci.* **23**, 6, 536-542, June 1956.

Measurements in the Ames supersonic free-flight wind tunnel on free-flying hollow-cylinder models at Mach numbers of 2.8, 3.8, 5.6, and 7.0. Due to the short flight time of the model, about 0.01 sec, the model wall-temperature rise was only about 15° to 45° above its initial value of ambient temperature of about 530R; whereas, recovery temperatures were about 1,300 to 3,200R. Then, high rates of heat transfer exist from the boundary layer to the wall. Under these conditions, skin friction of a turbulent boundary layer, computed from deceleration data, is appreciably higher than the skin friction measured in wind tunnels with zero heat transfer (approximately 35% higher at the same Mach number). These results confirm qualitatively the conclusions of many analyses that differ widely in magnitude. Authors slightly modified the T' method of Rubesin and Johnson to fit experimental data.

Reviewer believes that heat transfer in this transient process with heat source in the boundary layer is different from normal heat transfer in steady flow. Further experiments appear necessary to confirm these findings. A. E. Brun, France

237. **Persh, J., and Sherwood, A. W., An experimental investigation of the boundary-layer flow on a rotating flat plate,** *J. aero. Sci.* 23, 7, 703-704 (Readers' Forum), July 1956.

238. **Glauert, N. B., The laminar boundary layer on oscillating plates and cylinders,** *J. fluid Mech.* **1**, 1, 97-110, May 1956.

Paper treats incompressible boundary layers in so-called stagnation flow when either the wall oscillates in its own plane and the outer flow is constant in time or the stagnation point fluctuates in its position and the wall is fixed. The exact solution is obtained as a single ordinary differential equation with frequency as parameter and is not restricted to small values of frequency. Oscillating cylinders are generally discussed in the light of preceding analysis, and in one example the over-all effects of small oscillations on the fluctuating torque are estimated.

H. Schuh, Sweden

239. **Ray, M., Velocity and temperature distributions in a forced jet of a compressible fluid,** *Bull. Calcutta math. Soc.* **47**, 3, 165-170, Sept. 1955.

Boundary-layer equations are applied to study of laminar steady flow in plane jet. Prandtl number is taken as unity and pressure gradient is assumed to be negligible. Furthermore, flow is assumed to be subjected to axial body force. To specify problem completely, either body force is assumed to be constant along jet axis and to vanish at jet edges, or flux of momentum across any section is taken as constant. J. V. Foa, USA

240. **Ribaud, G., and Valentin, P., Study of forced heat convection with heat energy production through chemical reaction in the boundary layer** (in French), *C. R. Acad. Sci. Paris* **243**, 5, 463-466, July 1956.

Aerodynamics of Flight; Wind Forces

(See also Revs. 22, 187, 192, 194, 196, 199, 250, 268, 269, 270, 320, 352)

241. **Kuessner, H. G., Investigation of the oscillating elliptic lifting surface in incompressible flow,** *AF tech. Rep.* AFOSR-TN-56-4, 49 pp., 1956.

Author obtains exact solution, satisfying the Laplace equation in ellipsoidal coordinates with products of Lamé polynomials. Majority of report is concerned with representation of Lamé, and characteristic functions of lifting surface theory, in terms of Weierstrassian and Jacobian functions and by trigonometric and associated Legendre functions. Most of these functions remain to be calculated.

Expressions are given for the forces and lower moments for bilinear downwash distributions. Results obtained for infinite aspect ratio and zero frequency show 20% to 40% variation with Prandtl's two-dimensional theory. Author suggests that Prandtl's square-root singularity at leading edge, the basis of all subsonic theory, is actually incorrect and that this fact partially explains differences with experiment previously considered boundary-layer and thickness effects. H. M. Voss, USA

242. **Heaslet, M. A., and Fuller, F. B., Axially symmetric shapes with minimum wave drag,** *NACA Rep.* 1256, 16 pp., 1956.

See AMR **8**, Rev. *3476*.

243. **de Leeuw, J. H., Eckhaus, W., and van de Vooren, A. I., The solution of the generalized Prandtl equation for swept wings,** *Nat. LuchtLab. Amsterdam Rep.* F. 156, 14 pp. + 13 tables + 3 figs. + appendixes, Sept. 1954.

Van de Vooren presented a generalized Prandtl equation for swept wing, which was obtained from the exact linearized lifting-surface equation. In this report, the solution of this equation is considered.

The general method of solution is applied to two swept wings, for which the spanwise lift distribution and the location of the sectional aerodynamic centers will be calculated. One of these wings is a flat wing, while the other is cambered and twisted over its outer part. The present method has been compared with the well-known Multhopp method and Weissinger method. The present method is simpler than Multhopp's method but not so accurate. It is good for swept wing of large aspect ratio. The computational work is of the same order as for calculations of Weissinger's method, but it gives the position of the aerodynamic center which cannot be obtained by Weissinger's method.

S. I. Pai, USA

244. **Legendre, R., Influence of discharge from a leaking jet upon flow around a profile with the jet** (in French), *C. R. Acad. Sci. Paris* **242**, 20, 2438-2440, May 1956.

Following Joukowsky's two-dimensional wing theory, a theoretical model is offered through the hypothesis of a vortex-free motion inside and outside of the jet, combined with two infinitely close vortex rows at the boundaries. The discontinuity of the outside velocity across the jet is found to be proportional to its curvature, when local singularities are not taken into account. Consequently, the complex potential of the outside flow is determined, and on the basis of some conditions to be satisfied a method is indicated for the evaluation of the geometrical shape of the jet.

A. Ghetti, Italy

245. **Malavard, L., Linearized theory of a jet leaking out from an airfoil** (in French), *C. R. Acad. Sci. Paris* **242**, 20, 2440-2442, May 1956.

The same problem of the preceding review is here treated by classical hypothesis on linearization. In this case the perturbation potential is given by an harmonic function, defined by special boundary conditions. Some interesting and practical applications are indicated, showing the possibility of numerical solutions through analytical calculations, or by a rheoelectric analogy method, which will be further illustrated.

A. Ghetti, Italy

246. **Shulman, Y., Stability of a flexible helicopter rotor blade in forward flight,** *J. aero. Sci.* **23**, 7, 663-693, July 1956.

Stability of transient flapping motion is determined on the basis of two-degree-of-freedom analysis — rigid flapping and elastic bending. Digital computer results are presented indicating that

effect of blade flexibility is substantial, reducing value of advance ratio for instability and providing better comparison with experimental results. G. Isakson, USA

247. Kaufman, L., and Peress, K., A review of methods for predicting helicopter longitudinal response, *J. aero. Sci.* **23,** 3, 259–271, Mar. 1956.

Paper contains comparison and discussion of the several degrees of approximations possible for predicting helicopter longitudinal response.

Under certain assumptions (specified in the paper), six general equations for the longitudinal motion are derived; they are written in terms of average rotor forces and first harmonic flapping moments and, in addition, it is assumed that lateral body motions have only a negligible effect upon the longitudinal forces and moments developed. The above said equations (3 for body motions and 3 for rotor flapping motions) are nonlinear; however, they are considered in the linearized form by studying the response to small perturbations about an initially trimmed configuration. Furthermore, on physical grounds, it appears reasonable to account for the effects of coning and lateral flapping separably, thereby reducing the equations to four. Further simplification is achieved when the lag between the tip rotor path plane and the rotor shaft is neglected, by eliminating the longitudinal flapping equation entirely (quasi-static approximation of Hohenemser). Finally, a correction to the quasi-static solution to account for the effect of rotor dynamics results in a method advanced by Ellis.

Analysis of S-55 helicopter response was performed for each of the three methods described, and comparison was made with flight tests results. A range of applicability can be assigned to each method. P. Santini, Italy

248. Brailsford, E. N., The aerodynamics of the helicopter in forward flight, *J. roy. aero. Soc.* **60,** 548, 523–542, Aug. 1956.

A detailed analysis of loads, for example for performance calculations, on a rotor is made. Lift, profile, and induced drag loads and torques, as well as rotor thrust and pitching and rolling moments about hub are obtained. Blade-element type of analysis is used, and coning angle, nonuniformity of induced downwash, root and tip losses, and tilting of the rotor disk plane are considered. Explicit procedures for calculation of the blade loadings are given. M. Morduchow, USA

249. Brantley, J. O., Jr., The in-flight collision problem, *Aero. Engng. Rev.* **15,** 7, 45–53, July 1956.

Aeroelasticity (Flutter, Divergence, etc.)

(See also Revs. 109, 238)

250. Li, T., Aerodynamic influence coefficients for an oscillating finite thin wing in supersonic flow, *J. aero. Sci.* **23,** 7, 613 622, July 1956.

In linearized theory, aerodynamic forces on oscillating wings in a supersonic stream can, in principle, be calculated from a well-known integral equation. Its solution in closed form or with help of series development is restricted to special planforms, special modes of oscillation, or limited frequency ranges. For arbitrary cases, a box method was developed by S. Pines, J. Dugundji, and J. Neuringer [AMR **9**, Rev. 1561], where the wing area is subdivided into a (great) number of squares. The influence of each square on all the other squares is calculated by solving the appropriate boundary-value problem. The choice of square boxes restricts applicability to Mach numbers above $M = (2)^{1/2}$.

Instead of square boxes, author uses rectangles with their diagonals parallel to the Mach lines. Effects of the wing edges and tips as well as the effect of subsonic leading edges can now be calculated even in the range $1 < M < (2)^{1/2}$. The influence coefficients as calculated by this method can directly be used in flutter calculations for arbitrary planforms and oscillatory modes. Method is suitable for use of high-speed computer. Results are given for the two-dimensional wing. They are in good agreement with known results. H. Merbt, Sweden

251. McCarthy, J. F., Jr., and Halfman, R. L., The design and testing of supersonic flutter models, *J. aero. Sci.* **23,** 6, 530-535, June 1956.

The basic problems of flutter testing in the low supersonic speed range (Mach number 1.2-2.1) are outlined. The requirements for models which simulate full-scale airplanes when Mach number is included as a parameter are reviewed and compared with those where velocity is scaled so that flutter occurs in the range of a low-speed wind tunnel.

A particular type of construction for supersonic flutter models is described in detail. Methods of vibration testing, static testing, and flutter testing are discussed. Particular emphasis is placed on the technique of varying flow parameters rather than model parameters to precipitate flutter. The tool for varying flow parameters is the variable Mach number supersonic test section of the Massachusetts Institute of Technology Blowdown Wind Tunnel. The aerodynamic features of the supersonic test section are presented. From authors' summary

252. Hubbard, H. H., Burgess, M. F., and Sylvester, M. A., Flutter of thin propeller blades, including effects of Mach number, structural damping, and vibratory-stress measurements near the flutter boundaries, *NACA TN* 3707, 25 pp., June 1956.

Experimental results are presented of an investigation on the flutter of propeller blades with three different planforms. Data for a proposed supersonic propeller having highly twisted 2-percent-thick blades indicate that the flutter boundaries are complex and that several modes of flutter are involved. Data for a 6-percent-thick blade for which both the high Mach number and the low Mach number flutter boundaries are obtained in detail indicate that Mach number effects can be beneficial in alleviating flutter. Results for two 3-percent-thick blades having different internal damping show that an increase in the internal damping is beneficial in reducing the magnitude of the stresses both during flutter and for conditions of blade resonance.

From authors' summary

253. Hjelte, F., Methods for calculating pressure distributions on oscillating wings of delta type at supersonic and transonic speeds, *Roy. Inst. Technol., Stockholm, KTH-Aero TN* 39, 29 pp., 1956.

Problem is to determine aerodynamic characteristics of oscillating three-dimensional wings with subsonic leading edges.

Linearized solutions are based on the Laplace transformation. Two methods of solution are derived, of which the first is an iterative method starting from results of slender-body theory. This method is applicable for relatively slender wings having continuous leading edge slope and for low reduced frequencies. The second method transforms the unsteady problem to an analogous steady-state problem. This method was derived for high frequencies or high Mach number but can be used for more general problems. It is, of course, restricted to planforms and mode oscillation for which the analogous stationary problem can be solved.

Results of applications of the methods for several configurations are presented in numerous figures. J. DeYoung, USA

Propellers, Fans, Turbines, Pumps, etc.

(See also Revs. 21, 32, 35, 38, 121, 167, 168, 169, 200, 211, 215, 246, 247, 248, 252, 307, 308, 313, 314, 323, 324, 325)

Book—254. Shepherd, D. G., Principles of turbomachinery, New York, The Macmillan Co., 1956, ix + 463 pp. $10.

The turbomachines considered are fans, blowers, radial-flow and axial-flow pumps and compressors which absorb power, and hydraulic turbines, steam turbines and gas turbines which produce power. After an introduction, four chapters treat general material which is applicable in part or whole to all types of turbomachines: Dimensional analysis, energy transfer between a fluid and a rotor, thermodynamics of gas flow, flow of fluids in turbomachines. The last six chapters belong to the several kinds of turbomachines: Centrifugal pumps and compressors, radial-flow turbines, axial-flow turbines, performance of turbines and comparison of types, axial-flow compressors and pumps, performance of compressors and pumps and comparison of types.

A. Betz, Germany

255. **Huppert, M. C., and Costilow, Eleanor L., Some aspects of rotating stall in single-stage compressors,** ASME Semiann. Meet., Cleveland, O., June 1956. Pap. 56-SA-57, 9 pp.

Single-blade-row rotating-stall theories are reviewed and the absolute stall-propagation rates compared with single-blade-row data. The rotating-stall characteristics of a variety of high hub tip-radius ratio single-stage multiblade-row configurations are presented. The data indicate that the absolute stall-propagation rate is independent of guide-vane turning and is reduced appreciably by a stator-row addition to a particular guide vane-rotor combination. Tests indicate the initiation of rotating stall in a multiblade-row system is dependent upon the over-all system characteristics of the blade-row configuration as well as the individual blade-row characteristics. A flow-stability criterion obtained from one of the theoretical analyses of rotating stall indicates that rotating stall will occur when the static pressure rise of a stage reaches a maximum. This criterion is in substantial agreement with single-stage data presented.

From authors' summary

256. **Legendre, R., Experiments on compressor airfoils** (in French), *Rech. aéro.* no. 51, 3–10, May/June 1956.

Low-speed wind-tunnel tests of two cascades of airfoils are reported and results compared with calculated values. Author believes ordinary velocity diagrams, with relative fluid velocity taken as average over flow passage, are largely meaningless or misleading, and emphasizes that the only rational method is to take account separately of boundary layer and free-stream phenomena. Object of such tests as are here reported is to obtain data to correct design calculations both for losses and for effect of boundary layer on effective passage areas. Author admits this is not possible at present because of still undetermined effect of blade rotation on boundary-layer phenomena, but he believes such an approach is the only promising means of eventually refining design process.

C. W. Smith, USA

257. **Blaho, N., and Szentmartony, T., Influence of the turbulence generated at the inlet of the axial flow fan upon its efficiency** (in Hungarian), *Magyar Tud. Akad. Oszt. Közl.* **18,** 1/4, 193–200, 1956.

The results of experimental investigations are presented relating to intake configurations of axial flow fans. It is shown that good intake design allows approximation of design efficiencies of the fans.

T. P. Torda, USA

258. **Spencer, E. A., The performance of an axial-flow pump,** Instn. mech. Engrs., Prepr., 10 pp., 1956.

Tests were made on an 11-in. diam axial-flow propeller pump with impeller and guide blades designed for free vortex conditions, using as a basis the modified airfoil theory. The best over-all efficiency obtained was 82%. Apart from head-flow and efficiency characteristics, measurements were made of velocities and yaw angles within the pump at the design flow of 6 cusecs and these showed where departures from the theoretical assumptions occurred.

Head-flow characteristics were obtained for various impeller blade-tip clearances from 0.015 to 0.060 inch (0.6 to 2.4% blade height) and it was deduced that secondary flows were not confined to the tip region alone, but extended across the whole annulus.

The pump was on an open circuit, so that cavitation tests were limited. Nevertheless, methods of increasing the resistance to cavitation susceptibility are considered.

It was concluded that despite the fact that some of the assumptions made in the theory are invalid, this method of design may be used with confidence for pumps in the specific speed range of approximately 8000.

From author's summary

259. **Hutton, S. P., Three-dimensional motion in axial-flow impellers,** Instn. mech. Engrs, Prepr., 11 pp., 1956.

Detailed surveys have been made of the flow through a low-pressure-rise axial-flow impeller (hub/tip diameter ratio 0.33), which did not produce 'free vortex' whirl distribution.

It was found that: (1) at all flows, centrifugal forces caused large variations in axial velocity component through the rotor; (2) the angular direction of the flow varied considerably within a short distance of the rotor, and the flow did not stabilize until about two blade chords downstream; (3) as the tip clearance was increased, secondary motion was induced opposite to the motion caused by centrifugal effects and, for clearances greater than 1% of the blade height, seriously restricted the use of radial equilibrium theory.

The measured head-flow characteristics for various sections along the impeller blades did not agree well with those calculated by the following two-dimensional design methods: (1) "slip" theory, (2) "cascade" theory, (3) "airfoil" theory. Better results were given by the use of a new method which consisted of two steps: (1) calculating the change in axial velocity by the radial equilibrium theory, involving the use of cascade data; and (2) calculating the head-flow characteristics, using the airfoil theory based on the mean axial velocity obtained from (1).

By this compromise the calculated local performance over most of the blade agreed within 4% of experiment for a wide range of flows between design point and the stall. The new method may be generally applicable to low-pressure-rise fans and pumps, but further experimental evidence will be required to confirm this.

From author's summary

260. **Gruber, J., Approximate determination of the velocity field of a vortex row with a gap,** (in Hungarian), *Magyar Tud. Akad. Oszt. Közl.* **18,** 1/4, 187–192, 1956.

The induced effects of a closely spaced blade cascade on a single blade are calculated by substituting vortex rows for all adjacent blades and computing (with certain approximations) their effect along the chord of the blade in question.

T. P. Torda, USA

261. **Lowenstein, M., Controlling a nuclear-driven gas turbine,** *Control Engng.* **3,** 10, 71–77, Oct. 1956.

Flow and Flight Test Techniques

(See also Revs. 161, 162, 177, 236, 256, 358, 360, 361)

262. **Winter, E. F., and Deterding, J. H., Apparatus and techniques for the application of a water flow system to the study of aerodynamic systems,** *Brit. J. appl. Phys.* **7,** 7, 247–260, July 1956.

Apparatus is described by means of which the flow of water may be studied in transparent models of the simulated air systems.

The flow is rendered visible by plastic tracers, of similar density of water, which are illuminated by continuous filament lamps, long-duration electronic flash lamps, or vapor discharge lamps, according to the information required.

From authors' summary by A. Petroff, USA

263. Catheron, A. R., and Hainsworth, B. D., Dynamics of liquid flow control, *Indust. Engng. Chem.* **48,** 6, 1042–1046, June 1956.

Dynamic performance of differential pressure transmitter, pneumatic transmission line, controller, pneumatic valve motor, and whole control system are studied experimentally. Improvements of control results by minimizing valve and other lags are demonstrated, deducing changes in controller adjustments due to change of flow rate transmitter from mercury type to faster dry differential type. Perspectives are given on frequency boundary of noise, and other future problems. Y. Takahashi, Japan

264. Ray, A. K., Influence of the pressure tap diameter upon the accuracy of statical pressure measurement at different Reynolds numbers (in German), *Ing.-Arch.* **24,** 3, 171–181, 1956.

Static pressure is measured through holes 2-10-mm diam in comparison with that through 1-mm diam hole in a water (sugar solution) channel. A good correlation is obtained for the pressure increase above extrapolated null-diameter pressure by means of a Reynolds number $(dV/dy)(d^2/\nu)$ where dV/dy is the velocity gradient at the wall surface, d the diameter of a hole, and ν the kinematic viscosity. F. R. Hama, USA

265. Jobson, D. A., On the flow of a compressible fluid through orifices, *Instn. mech. Engrs. Proc.* **169,** 37, 767–776, 1955.

A method is derived for predicting the flow of a compressible fluid through any orifice for which the coefficient of contraction C_i for an incompressible fluid is known. The method assumes that a dimensionless "force defect coefficient" f (in effect a drag coefficient equal to the drag on the jet divided by twice the velocity force of the jet) is constant at high velocities, regardless of whether the fluid is compressible or incompressible.

It is first shown that $f = 1/C_i - 0.5/C_i^2$. The expressions for the subcritical and supercritical coefficient of contraction are then derived, in terms of f, the pressure ratio across the orifice, and the isentropic expansion exponent ($C_p C_v$ for a perfect gas). The agreement with experimental data for both air and steam is satisfactory. C. F. Bonilla, USA

266. Zeek, E. R., and Hammill, I. J., Crash fire prevention—Research to flight test, *Aero. Engng. Rev.* **15,** 7, 40–44, July 1956.

267. Heitkotter, R. H., Flight investigation of the performance of a two-stage solid-propellant Nike-Deacon (DAN) meteorological sounding rocket, *NACA TN* 3739, 21 pp., July 1956.

Two Nike-Deacon (DAN) two-stage solid-propellant rocket vehicles were flight tested to evaluate their use as meteorological sounding rockets. The vehicles contained upper atmosphere research apparatus which was ejected in flight, and the flight paths were determined by using radar beacon instrumentation. The radar beacon instrumentation recorded a peak altitude of 356,000 ft during the first flight test and 350,000 ft during the second flight test when both vehicles were launched from sea level at an angle of elevation of 75°. Satisfactory performance of the DAN meteorological sounding rocket was indicated from the results of the flight tests conducted. Performance calculations based on flight-test results show that altitudes between 358,000 ft and 487,000 ft may be attained with payloads varying between 60 pounds and 10 pounds. From author's summary

268. Pittel, M., Flight tests at supersonic speeds to determine the effect of taper on the zero-lift drag of sweptback low-aspect-ratio wings, *NACA TN* 3697, 20 pp., June 1956.

Rocket-powered models have been flown to provide an experimental comparison with linearized theoretical calculations for zero-lift drag of sweptback tapered wings having thin, symmetrical double-wedge air-foil sections. The range of experimental data is from a Mach number M of 1.0 to 1.8, and theoretical comparisons are made for the test range above $M = 1.2$.

The linearized theory compared very favorably with experimental results over most of the test range. For a given thickness and aspect ratio, taper generally increased the wing drag at low supersonic speeds but reduced the drag at higher speeds. For a given thickness and taper ratio, wings of aspect ratio 4 had less drag below $M \approx 1.2$, but greater drag above $M \approx 1.2$, than the wings of aspect ratio 2. From author's summary

269. Kerr, T. H., Full scale spinning tests on the Percival Provost Mk. 1 including the inverted spin, *Aero. Res. Counc. Lond. curr. Pap.* 240, 10 pp. + 4 tables + 20 figs., 1956.

Instrumented spinning tests on this aircraft were completed in both the normal and inverted attitudes. The normal spin showed the characteristics of the smooth and oscillatory type, depending upon the control configuration; being oscillatory with pro-spin aileron and smooth with anti-spin aileron. The recovery was satisfactory in each case.

Inverted spins of up to six turns were completed and showed satisfactory characteristics both for the spin and the recovery.

From author's summary

270. Fink, P. T., Wind-tunnel tests on a slender delta wing at high incidence, *Z. Flugwiss.* **4,** 7, 247–249, July 1956.

Experiments are described which have helped to form a consistent picture of the flow past slender delta wings at angles of incidence at which leading edge separation is found. Agreement with the available theory is found to be indifferent.

From author's summary by E. Eujen, Germany

271. Woods, L. C., On the thrust to an air jet flowing from a wing placed in a wind tunnel, *J. fluid Mech.* **1,** 1, 54–60, May 1956.

Author considers a wing-jet combination placed in a wind tunnel and quickly obtains equations giving the exact mathematical solutions under the assumption that (1) the flow is isentropic, (2) there is no mixing of the jet and main stream fluids, (3) any vorticity is confined to vortex sheets. Although this idealization is only an approximation to the actual flow, a comparison may give useful information concerning the loss of jet efficiency due to viscosity and turbulence. The case where the model dimensions are small compared with those of the wind tunnel is discussed in detail, and it is shown that the ideal thrust is almost independent of the jet exit angle. Some wind-tunnel corrections are given.

G. Power, England

Thermodynamics

(See also Revs. 154, 172, 209, 215, 289, 291, 307, 315, 343, 344, 346)

Book—272. Hund, F., Theoretical physics. Thermodynamic quantum theory, Vol. I. [Theoretische Physik. Wärmelehre und Quantentheorie], Stuttgart, B. G. Teubner Verlagsgesellschaft, 1956, viii + 400 pp.

Dr. Hund's revised edition of volume three of his well-known introductory treatises on theoretical physics deals with thermodynamics and quantum mechanics. The avowed objective of the

book is to clarify the methodology and point of view of modern physics and to illustrate fundamental concepts and difficult abstractions by simple examples. Author's objectives are well met by his discussion.

The development of the fundamentals of thermodynamics follows a conventional sequence: temperature concept, equations of state, heat and thermal conduction, the laws of thermodynamics (including selected applications), irreversible processes, statistical interpretation of temperature and entropy (chaps. I through V). The chapter on applications of thermodynamics (chap. VI) includes consideration of such topics as phase changes, chemical equilibrium, a very brief section on processes involving magnetic effects, and Nernst's theorem. Many topics in applied thermodynamics, which are of most immediate interest in connection with current engineering problems, are not considered.

The chapter on classical statistical mechanics (chap. VII) is concise and contains a brief discussion of the potential energy of harmonic oscillators. By contrast, the classical treatment of thermal radiation (chap. VIII) is fairly detailed.

In the survey of atomic structure, brief mention is made of transport processes and line spectra (chap. IX) before the subject of quantum mechanics (chap. X) is introduced with consideration of Planck's radiation formula, specific heat of solids, and Bohr's theory of the hydrogen atom. A detailed consideration of the correspondence principle precedes the study of atomic energy levels, the periodic tables, the vector model of the atom, Compton effect, fluctuation theory, etc. (chaps. XI and XII). Wave mechanics and quantum theory for individual particles, based on the use of Schrödinger's wave equation, constitute chaps. XIII and XIV. Author concludes the book with a discussion of systems composed of many particles, followed by a survey of some fundamental principles of quantum theory, viz., analogy between vectors and matrixes principles of complementarity and uncertainty (chaps. XV and XVI). A historical survey is appended.

The book is well printed and has a useful subject index.

S. S. Penner, USA

Book—273. **Patterson, G. N., Molecular flow of gases,** New York, John Wiley & Sons, Inc.; London, Chapman & Hall, Ltd., 1956, x + 217 pp. $7.50.

This little book gives an excellent review for making the transition in outlook from the continuum to the moelcular viewpoint on a university graduate level. Author is known from his contributions to the engineering and aerophysical aspects of fluid dynamics based upon the kinetic theory. Book presents very good material for an engineering graduate course, and as such is strongly recommended.

In chap. I are presented the fundamentals of the mathematical model of the molecular theory of gases, including Boltzmann's equation. In chap. II this is applied to isentropic flow with some particular applications like expansion in one- and two-dimensional flows. In chap. III, the basic equations of nonisentropic (viscous, heat-conducting) flow are given. This type of flow is widely discussed in chap. IV: shock transition, diffuse reflection from a solid boundary, transfer of momentum and energy, boundary layer, slip flow, etc. Chapter V contains mechanics of rarefied gas (free-molecule flow): momentum and energy exchange at a surface, temperature jump, slip flow, transition regime, etc.

Book contains a large amount of engineering data, large number of references, is nicely printed, and the light style makes it easy to read. It should find its place in the library of every modern aerodynamist.

M. Z. Krzywoblocki, USA

274. **Blackman, V., Vibrational relaxation in oxygen and nitrogen,** *J. fluid Mech.* **1**, 1, 61-85, May 1956.

The Rankine-Hugoniot equations with constant specific heat ratio are not accurate for shock waves of Mach number $M \geqslant 2$, and for temperatures much above a few hundred degrees Kelvin. For these strong shock waves, the equilibrium temperature T_2 behind the shock is so high that vibrational modes of a diatomic gas become excited and the specific heats cannot be regarded as constant. Assuming that the shock strength and the temperature T_2 are not large enough to make dissociation and ionization effects appreciable, author makes interferometeric studies of strong shocks, $M_1 = 3-7.5$ in oxygen and $M_1 = 5-10$ in nitrogen. The experimental results agree well with the calculated results by the Bethe-Teller theory [*Univ. Mich., Engng. Res. Inst.* 1951].

Reviewer notes that the experimental technique for producing strong shocks is ingenious.

S. D. Nigam, India

275. **Hellund, E. J., Temperature dependence of the viscosity of liquids,** *J. chem. Phys.* **24**, 6, 1173-1174, June 1956.

The consequences of the introduction of long-range disorder into the theory of the liquid state are examined. Application is made to the analysis of viscosity.

From author's summary

276. **Dekker, A. O., Rapid estimation of specific impulse of solid propellants,** *Jet Propulsion* **26**, 7 (part 1), 572-575, July 1956.

The short method of Hirschfelder and Sherman for calculation of the thermodynamic properties of gun propellants is adapted to the quick estimation of specific impulse of solid propellants for rockets. When this approximate procedure is applied to a series of propellants with flame temperatures equal to or greater than 2000 K and specific impulses of 200 to 245 lbf sec lbm^{-1}, at 1000 psia the results are within about 2% of those given by the detailed thermodynamic method which assumes mobile equilibrium. For a propellant ingredient which forms only gaseous products, it is necessary to know only the empirical formula and heat of formation from which a set of three additive constants is calculated in less than ten minutes. The specific impulse of any particular combination can then be estimated from the additive constants for the components in less than five minutes. The method is limited to cases with negligible dissociation and to fuel-rich mixtures.

From author's summary

277. **Touloukian, Y. S., and Lykoudis, P. S., Thermodynamics of the first order,** 1956 Heat Transfer and Fluid Mechanics Institute, Stanford, Cal., Prepr. 15, 22 pp.

Thermodynamics of the first order is defined in terms of the thermoelectric effect in which heat flux E_T is expressed as a function of gradient temperature and gradient electric potential. MacLaurin's expansion of this function at the condition of zero gradients gives a sum of the following terms: E_T at zero gradients, linear terms involving first derivatives of E_T with respect to gradients, and nonlinear terms. In classical thermodynamics (thermodynamics of the zeroth order), all but the first term are neglected; in thermodynamics of the first order all nonlinear terms are neglected. The development of the science of thermodynamics is one step behind that of elasticity, electricity, and fluid flow which are already utilizing second-order terms.

The term "ektropy" is introduced for the difference between ΔS and $\int(dQ/T)$. The rate of generation of ektropy is expressed in terms of flows of heat, electricity, and matter, and their characteristic gradients. The steady state is related to the state of minimum ektropy production.

An appendix gives a proof of Onsager's reciprocal relations in terms of fluctuation theory.

Since no new material is presented, this paper must be considered as exposition. In the opinion of the reviewer, though some aspects of the subject are brought into clear relationship, certain vital points are omitted and several obscurities remain unilluminated. The authors' conclusion that classical thermodynamics is a science which deals only with processes of zero ektropy production should be modified in view of Gibbs' treat-

ment of processes in isolated systems by reference to changes in entropy. J. H. Keenan, USA

278. Roy, M., Efficiency and pressure loss relative to the combustion chamber in aircraft jet engines and in combustion turbines (in French), *Z. Flugwiss.* **4,** 5/6, 190-194, May/June 1956.

Author discusses efficiency and pressure drop in a simple continuous-flow combustion chamber. A comparison of the ideal and real behavior in such a system is made in terms of the pertinent thermodynamic and flow parameters. The factors that affect efficiency and pressure drop are discussed, and their effects illustrated in enthalpy diagrams for the system described. The effects of assuming constant temperature and pressure within the system are considered, and a definition of efficiency is proposed that includes these effects. J. S. Arnold, USA

Heat and Mass Transfer

(See also Revs. 56, 109, 145, 191, 193, 222, 236, 239, 240, 272, 307, 315)

Book—279. Crank, J., The mathematics of diffusion, New York, Oxford University Press, 1956, vi + 347 pp. $8.

This tome contains a vast storehouse of information. Material is applicable to other fields where phenomena are described by partial differential equations identical to the diffusion equation (e. g., heat conduction) or similar in form to it. The first chapter gives a formal derivation and discussion of the diffusion equation. Chapters II to VIII consider a wide class of problems where the diffusivity factor is constant. Here the Laplace transform plays the dominant role, and this part of the volume is developed from the well-known book "Conduction of heat in solids" by Carslaw and Jaeger. Subjects covered in this portion are infinite and semi-infinite media; diffusion in a plane, cylinder, and sphere; diffusion with a moving boundary; and simultaneous diffusion and chemical reaction.

Analytical methods of solution for variable diffusivity are given in chap. IX, while chap. X considers finite difference techniques. The latter chapter could stand improvement. The question of stability is hardly touched upon, and the valuable treatise by Collatz [AMR **5**, Rev. 1598; **8**, Rev. 2203] is not even mentioned in the references. In this regard, there are a number of recent papers in the literature bearing on the subject. These have appeared after the apparent cut-off date for references used by the author. Workers will do well to consult same, especially when large-scale computing equipment is available.

Measurement of diffusion coefficients is the subject of chap. XI. Chapter XII presents calculated results in graphical form for a variety of problems involving variable diffusivity. This is an excellent feature of the chapter. In fact, a noteworthy aspect of the entire volume is the collection of over a hundred such solutions covering the many topics discussed. These data should prove useful to many workers. Simultaneous diffusion of heat and moisture is the subject of the final chapter.

An extensive list of references is provided at the end of each chapter. Tables of the error function and associated functions, and a short table of Laplace transforms are provided in the appendix, together with tables of zeros of functions arising in the mathematical theory. There are several miscellaneous tables. To illustrate some of the numerical techniques developed for solution, several sections of computational formats are also given.

Y. L. Luke, USA

280. Reid, W. P., Heat flow in a half space, *Quart. appl. Math.* **14,** 2, 206-208, July 1956.

At the front surface $\chi = 0$ of the homogeneous and isotropic half space $\chi > 0$, there is a very thin slab of high thermal conductivity. Combining the Laplace and Fourier sine transforms, author solves elegantly the one-dimensional heat flow problem in the above system when there is radiation of heat at both surfaces of the slab, initial temperature in $\chi > 0$ being a general function of χ only and the temperature in the other surroundings of the slab a prescribed function of the time.

Of course, resulting formulas giving the solution both in the region $\chi > 0$ and in the slab are extremely complicated. Nevertheless, this does not diminish in any way the theoretical and technical value of this fine paper enriching the advanced theory of heat conduction as well as the field of applications of methods solving important problems of mathematical physics by a suitable combination of various integral transforms.

Presentation is very compact and the study presupposes certain familiarity with the theory of Fourier transforms. Reviewer considers the subject to be an original one and recommends it warmly to interested engineers and physicists.

V. Vodicka, Czechoslovakia

281. Vernotte, P., Heat transfer of a slab with periodic heat flux at the origin and physical properties dependent on the temperature (in French), *C. R. Acad. Sci. Paris* **242,** 24, 2808-2810, June 1956.

The temperature dependence of the thermal conductivity, heat capacity, and film coefficient is considered as "mild" or linear. The analysis shows that from iterative approximations, using a few experimental points, a good approximation of the heat conductivity and the film coefficient and their temperature dependence can be obtained. S. Eskinazi, USA

282. Shilkrut, D. I., One problem of heat conduction for two media (in Russian), *Prikl. Mat. Mekh.* **20,** 2, 284-288, Mar./Apr. 1956.

This is an elegant generalization of a problem solved by Dobryshman [AMR **8,** Rev. 1160]. The amount of heat flowing to the separating plane $\chi = 0$ of the two media is now given by an arbitrary function $w(t)$ having a Laplace transform, and the solution is valid for all values of the time t (and not only for small values, as in the former paper by Dobryshman).

Author's solution follows with the aid of the Laplace transformation method in form of two contour integrals and is illustrated by concrete examples. Reader's attention is called especially to the interesting case of an instantaneous amount of heat $w(t)$. This problem cannot be treated by the method given by Dobryshman.

Reviewer takes the paper for a very fine and applicable contribution to the advanced theory of heat conduction and recommends it warmly to calculating engineers and physicists.

V. Vodicka, Czechoslovakia

283. Otis, D. R., Electric analogy to transient heat conduction in a medium with variable thermal properties, Proc. Nat. Simulation Conf., Dallas, Texas, Jan. 1956. Pap. 3, 4 pp.

A method is presented for the electronic simulation of transient heat conduction where the thermal properties of the conducting medium are considered as arbitrary functions of the temperature. The method involves the transformation of the heat-conduction equation to a form that is analogous to the equation describing an electrical lumped-parameter R-C system whereof the resistance can be varied by servo drive that can be successfully instrumented. The analysis is presented for an unidimensional heat-flow problem in rectangular coordinates. Comparison between values obtained on the computer and by Dusenberre's finite difference procedure agree within 3%.

T. J. Higgins, USA

284. Hamburger, L., Transformation of variables in the heat conduction equation (in French), *Acad. Repub. pop. Rom. Rev. Mecan. appl.* **1**, 1, 203-214, 1956.

Author studies the equation for unsteady heat conduction in an n-dimensional, uniform, but anisotropic solid. He derives the possible variable transformations which leave the basic equation unchanged in form; these are either a simple linear combination or an inversion of the time. Thus the paper is an extension of Appell's treatment of the one-dimensional case. Author refers to Appell, but does not list the work in the bibliography

R. R. Hughes, USA

285. Fieber, H., and Selig, F., Temperature fields due to moving heat sources in bodies of finite extension (in German), *Öst. Ing.-Arch.* **10**, 1, 96-103, 1956.

Sources of heat are specified in the equation of thermal conduction by means of delta functions or products of delta functions. Movement of the sources is described by letting the argument of the delta functions depend upon the time. The following systems are considered: A linear source moving along the central plane of a plate; a point-source moving along the outer surface of a hollow cylinder in direction of the axis or along a circle perpendicular to the axis; a plane source sweeping out a toroidal body. In all these examples, analytic solutions are obtained in relatively simple form by means of Fourier or Bessel transformation. For the torus, a graph is added which shows the temperature distribution. The authors claim that these results can be applied to heat flow during welding.

R. Eisenschitz, England

286. Masters, J. I., Problem of intense surface heating of a slab accompanied by change of phase, *J. appl. Phys.* **27**, 5, 477-484, May 1956.

When a meteor or satellite enters the earth's atmosphere, the surface of the body melts in consequence of rapid heating. Melting rate and temperature distribution are calculated on basis of one-dimensional heat-conduction theory with aid of finite-difference technique. Upper bound for melting rate is obtained through assumption that all molten metal is removed mechanically by air flow; approximate lower bound is found when removal is due entirely to evaporation.

N. J. Hoff, USA

287. Lal, S., Heat transfer in compressible laminar boundary layers, Part I, *J. aero. Soc. India* **8**, 1, 1-17, Feb. 1956.

In part I, the Illingworth-Stewartson transformation is applied to the boundary layer to reduce the mainstream Mach number to zero. It is shown how the Karman-Pohlhausen method may be applied to integrate the new equations.

K. Stewartson, England

288. Lal, S., Heat transfer in compressible laminar boundary layers, Part II, *J. aero. Soc. India* **8**, 2, 19-34, May 1956.

In part II, the Mach number of the mainstream is assumed to be zero. The effect of heat transfer on the velocity profile is considered for general values of the Prandtl number, using the Karman-Pohlhausen approximation. Some numerical examples are given.

K. Stewartson, England

289. Diamond, J., and Hall, W. B., Heat removal from nuclear-power reactors, Instn. mech. Engrs. Prepr., 14 pp., Mar. 1956.

Paper discusses the cooling of reactor fuel containers encasing solid fuel rods, which involves many factors such as temperature limitation on container and fuel, reaction with the coolant and container, dimensions of coolant channels and gaseous versus liquid coolants. The general heat-transfer problem is described where simple mathematical neutron densities relationships are used.

Appendixes contain: (1) detailed mathematics of relation of coolant temperature using sinusoidal flux distribution; (2) calculations of pressure drops and comparison of coolants; (3) the choice of parameters to give optimum conditions for a gas-cooled reactor, with comments on finned fuel elements; (4) an analysis of temperature distribution in a cylindrical fuel rod.

Author comments on ancillary cooling problems of the shield, moderator, framework, control rods, and residual heating due to decay of fission products. Article is good in showing that the design of nuclear-power reactors is related to all engineering knowledge.

H. Majors, Jr., USA

290. Ribaud, G., Heat transmission inside a pipe in turbulent flow (in French), *C. R. Acad. Sci. Paris* **242**, 8, 959-964, Feb. 1956.

A formula is derived for the coefficient of heat transfer as a function of the Prandtl number, by taking together the laminar boundary layer and the transition layer with one expression for the velocity distribution. It is shown that this formula gives better agreement with experiments than the formulas proposed by Martinelli [*Trans. ASME* **69**, p. 947, 1947], especially for high Prandtl numbers. The coefficient of heat transfer according to Martinelli is about two times too low for Prandtl numbers of the order of 100.

J. A. Businger, USA

291. Hirschfelder, J. O., Heat transfer in chemically reacting gas mixture, *Univ. Wisc., Nav. Res. Lab.* Rep. WIS-ONR-18, 27 pp., Feb. 1956.

Heat transfer between walls at fixed temperatures is calculated for the nonflowing reacting chemical system. Assuming chemical equilibrium as first approximation, species and temperature distribution, energy and mole fluxes are obtainable from conservation, transport, and chemical kinetic equations. Systems $A \rightleftharpoons B$, and oxygen dissociation are treated. Generally, chemical equilibrium assumption cannot satisfy boundary conditions, but departures are confined principally to a boundary-layer region small compared with wall separation. Solution in the boundary-layer region shows the considerable change to be expected in heat transfer due to energy transport by diffusion. Calculation of the effect of heterogeneous reaction at the wall does not indicate appreciable increase in heat flux due to high rate of surface recombination. Treatment permits investigation of Eucken correction for frozen internal degrees of freedom for polyatomic molecules. Empirical value of one for Prandtl to Schmidt number ratio suggests a new Eucken correction factor.

Paper represents very valuable addition to engineering applications of heat effects in reacting systems. Interesting adjunct paper is Franck and Spalthoff [*Z. Elecktrochem., Ber. Bunsengesellschaft phys. Chem.* (B) **58**, H 6, 374, 1954].

M. Gilbert, USA

292. Barrow, H., Asymmetric heat transfer to gases in turbulent flow between parallel plates, *J. roy. aero. Soc.* **60**, 546, 413-415 (Technical Notes), June 1956.

Paper derives an equation for the Nusselt number in heat-flow problem given in the title (heat is transferred to the fluid through one plate, the other being adiathermal), based on an extension of analogy between heat transfer and fluid friction by Mizushina [*Instn. Mech. Engrs. Proc.* p. 191, 1951]. Results, which are probably most accurate for gases, indicate that the ratio of *Nu* for asymmetrical heating to that for symmetrical heating is about 0.75 for gases and about 0.88 for water.

F. Krupka, Czechoslovakia

293. von Schlippe, B., Flow of liquids with temperature-dependent viscosity (cooling of oils) (in German), *Dtsch. Versuch. Luftfahrt E. V. Rep.* 9, 44 pp., Jan. 1956.

Proof was developed that, when cooling oils in laminar flow at a fixed velocity in a tube, the maximum cooling effect becomes independent of the tube wall temperature. The temperature and velocity distributions across the tube are considered. A generalized solution is presented for viscous fluids.

W. L. Sibbitt, USA

294. Blokhintsev, D. I., Minashin, M. E., and Sergeev, Yu. A., Physical and thermal calculations for the USSR Academy of Sciences atomic power station reactor, *Soviet J. Atomic Energy* no. 1, 21–41, 1956. (Consultants' Bureau Translation).

Paper describes the Soviet Union 5-MW atomic power reactor which is of the carbon-pile type. The "physics" calculations described in the first part are based on the "age" theory [cf S. Glasstone and M. Edlund, "The elements of nuclear reactor theory," D. Van Nostrand Co., Inc., New York, 1952]. The "thermal" calculations described in the second part outline briefly the method for taking into account such things as the nonuniformity of heat-source distribution within the core. The heat-source peaking factor is assumed proportional to the thermal flux peaking factor. Details are lacking as to the exact manner in which the peaking factor is applied to the design. Some calculated fuel and coolant temperature curves are presented along with calculated and experimental curves of the radial thermal flux distribution. From the figures, it appears that the theoretical radial peaking factor would be quite different from the experimental value, depending on the position of the inner and outer control rod banks. For a more detailed discussion of peaking factors and thermal design see the paper by Palladino [AMR **8**, Rev. 1177], now published in ASME Trans. **77**, 5, 667–673, July 1955. (Palladino's paper is good background material which will aid in interpretation of material in paper being reviewed.)

The problem of determining the heat sources and temperature distribution in the graphite moderator is peculiar to this type of reactor as contrasted to water-moderated reactors. The methods used for estimating the heat release in the graphite are discussed, but a number of errors in translation make it necessary for the reader to be careful. Transient behavior is also discussed.

The paper is a very interesting and useful survey of reactor design problems, many of which are present in all types of reactors.

R. S. Wick, USA

295. Brun, E. A., Brunello, G., and Vernotte, Magdeleine, Experimental study of forced heat convection for cylinder with wrinkled surface (in French), *Publ. sci. tech. Min. Air, France NT* 60, 33 pp., 1956.

Heat convection coefficients for the external surface of smooth and wrinkled pipes placed in a flow of air have been determined by authors. The pipes were internally heated by a flow of water. The air was moving in a direction normal to the axis of the same pipes. The wrinkles were of pyramidal form.

For smooth surfaces authors have found

$$Nu = 0.136\ Re^{0.65};$$

for wrinkled surfaces

$$Nu = 0.0425\ (\epsilon/D)^{0.27}\ Re^{0.9}$$

with Re between 6000 and 15,000. D is the external diameter (5 or 8 mm); ϵ the height of the wrinkles.

C. Codegone, Italy

296. Bialokoz, J. E., and Saunders, O. A., Heat transfer in pipe flow at high speeds, Instn. mech. Engrs. Preprint, 13 pp., 1956.

Measurements were made of adiabatic friction and of heat transfer for air flowing in tubes at Mach numbers up to 1.6, Reynolds numbers Re ranging from 1.24 to 4.35×10^5, free-stream air temperatures T_b of 190 to 286 K, and ratios of wall-to-free-stream temperature T_w/T_b of 1.08 to 1.73.

By careful control of entrance condition, and by minimizing pressure gradients in the tube (by constructing test sections with angles of divergence ranging from 10 min to 1 degree, 10 min), authors have been able to achieve excellent correlation (bulk of data within ± 5%) with the equation

$$St_b = 0.022 Re_b^{-0.2}\ Pr_b^{-0.6}\ (T_w/T_b)^{-0.5},$$

whose form is by now fairly standard for high-speed flow with large temperature differences. By performing several runs with shock waves in the tube, authors show that introduction of pressure gradients and less established flow conditions results in considerable increases in the Stanton number.

Friction factors (without shock) were correlated well by an equation which lies 4% above the von Karman relationship:

$$[1(4f)^{1/2}]\ (T_b/T_w)^{0.5} = -0.8 + 2 \log_{10} [(4f)^{1/2}\ Re\ (T_w/T_b)^{-1.2}]$$

Recovery factors calculated from the adiabatic runs were close to $(Pr)^{1/2}$, i.e., 0.84.

Reviewer notes with interest that first named author is conducting further experiments on obviously important effects of pressure gradient.

R. L. Mela, USA

297. Brevoort, M. J., and Rashis, B., Turbulent-heat-transfer measurements, *NACA TN* 3599, 13 pp., Dec. 1955.

Experimental setup consisted of outer cylindrical sleeve and inner central body shaped to provide constant Mach number of 0.5. Thirty-six thermocouples in sleeve measured the temperature as system was cooled by the air stream. Air stream stagnation temperature decreased slowly during a run. From thermocouple temperature-time history the recovery factor r and heat-transfer coefficient h were calculated. Results given are that r decreases slightly with distance x, and h agrees with Van Driest's flat plate theory, or roughly $h \sim x^{-1/5}$.

Reviewer does not understand these results. According to authors, sleeve temperatures in the test region were found to be independent of x. Therefore the temperature-time history of all thermocouples was identical, and h and r must both be independent of x.

L. M. Mack, USA

298. Johnson, D. S., Turbulent heat transfer in a boundary layer with discontinuous wall temperature, *Johns Hopkins Univ. Dept. Aero.* OSR TN 55-289, 95 pp. + 35 figs., Aug. 1955.

Paper deals with the experimental investigation of the velocity and temperature, in the turbulent boundary layer (zero-pressure-gradient) of a flat plate, downstream of a small stepwise discontinuity of the temperature of the wall. First, the mean velocity and mean temperature profiles, the momentum thickness of the boundary layer, and convection thickness of the thermal layer are compared; next, the second-order correlations R_{uv} $R_{u\theta}$, $R_{v\theta}$ (u, v, θ velocity and temperature fluctuations) and some third-order correlations are given.

The following general results are stated: (a) there does not appear to be similarity between the mean velocity and mean temperature profiles; (b) the boundary between heated and unheated air remains sharp; (c) temperature-fluctuation signals are intermittent near the edge of the thermal layer even though the velocity field may be fully turbulent at the same point; (d) after a sharp drop in the initial region, the local friction temperature and Nusselt number remain almost constant with distance from the leading edge.

J. Kampe de Feriet, France

299. Schuh, H., A new method for calculating laminar heat transfer on cylinders of arbitrary cross section and on bodies of revolution at constant and variable wall temperature, *Roy. Inst. Technol., Div. Aero., KTH Aero TN* 33, 40 pp., 1953.

The method developed here for calculating laminar heat transfer on variously shaped bodies with constant fluid properties and without heat generation involves a novel choice of dependent variable which is a function of the ratio of heat flow across the whole boundary layer to the temperature gradient at the wall in a suitable dimensionless form. The method is applied to the cases of uniform wall temperature, prescribed wall-temperature distribution, and uniform heat flux. Paper includes a discussion of and comparison with other analytical methods and with experimental data.

W. M. Rohsenow, USA

300. **Wheeler, H. L., Jr., and Duwez, P., Heat transfer through sweat-cooled porous tubes,** *Jet Propulsion* **25**, 10, 519–524, Oct. 1955.

Heat transfer and pressure drop in sweat-cooled porous tubes is investigated experimentally for H_2 and N_2. The heat-transfer results are compared with a simplified theoretical equation and are also interpreted in terms of a heat-transfer coefficient. It is shown that the pressure drop is given with reasonable precision by the sum of a frictional component and a momentum change component.

W. M. Rohsenow, USA

301. **Fax, D. H., and Mills, R. R., Jr., Generalized optimal heat-exchanger design,** ASME Semiannual Meet., Cleveland, O., June 1956. Pap. 56-SA-19, 6 pp.

Authors show the procedure used to design optimum gas-turbine regenerators based on the method of Lagrangian multipliers. Although several solutions exist in the literature, authors developed a generalized method which clearly shows the interrelationship between different problems of the same general class. Following a special derivation for the development of the necessary relations, authors present solutions for three problems dealing with a cross-flow plate-fin-type gas-turbine heat exchanger. One advantage of the method is that it does not require the explicit solution for the Lagrangian multipliers themselves. Authors feel that the method, when applied to problems of process and plant design, will lead to more of an insight into the synthesis of the mathematical statement of the problem, and a simpler solution than in the case for many of the existing methods.

G. A. Hawkins, USA

302. **Lees, S., and Hougen, J. O., Pulse testing a model heat exchange process,** *Indust. Engng. Chem.* **48**, 6, 1064–1068, June 1956.

Carefully selected displaced cosine pulse is applied to water flow rate through test heat exchanger, keeping heating steam condition constant. From recorded outlet water temperature, the system frequency response is computed by IBM computer. Good agreement of the result with direct frequency-response tests is shown on model exchanger. The method is thought to be less expensive than frequency-response test.

Y. Takahashi, Japan

303. **Zoss, L. M., Gollin, N. W., and Edelman, R. I., Dynamic response analysis of air heater temperature control system,** *Indust. Engng. Chem.* **48**, 6, 1069–1073, June 1956.

Control system performance is theoretically predicted and confirmed experimentally, showing how to improve controllability. Treated system is air heater with temperature controller which regulates steam flow to heater. Controlled system transfer function is two lags, one zero plus dead time type. Three cases of different measuring points and transmitters are discussed, comparing natural oscillation period ranging from 5.5 to 2.9 minutes. Plant re-design will result in a further improvement of 0.5 minutes period.

Y. Takahashi, Japan

304. **Cohen, W. C., and Johnson, E. F., Dynamic characteristics of double-pipe heat exchangers,** *Indust. Engng. Chem.* **48**, 6, 1031–1034, June 1956.

One simple special case of tubular heat exchange in which one fluid temperature is uniform throughout the system, such as water heater using saturated steam, is analytically solved for transfer functions. The transfer functions are defined as Laplace transformed temperature ratios of outlet water versus steam in one case, the same versus inlet water in the other case. As the derivation starts from partial differential equations of the distributed parameter system, exponential term appears in the transfer function, hence possible humps on Bode plot. Frequency-response test result for steam temperature forcing is compared with theoretical result on Bode diagram.

Numerical result estimated from experimental time response is also compared, with discussions for causes of discrepancies between various results.

Y. Takahashi, Japan

305. **Mozley, J. M., Predicting dynamics of concentric pipe heat exchangers,** *Indust. Engng. Chem.* **48**, 6, 1035–1041, June 1956.

Simplified analytical formulas and electrical analog method are given for predicting heat-exchanger response to input temperature variation. The transfer functions derived are of second order, representing lumped heat capacities of fluids. The C-R-type electrical analog is for five lumped sections of the system. Experimental, analog, and calculated frequency responses are compared, showing good agreements except for the calculated phase shift near $-180°$.

Y. Takahashi, Japan

Book—306. Treybal, R. E., Mass-transfer operations (McGraw-Hill series in chemical engineering), New York, McGraw-Hill Book Co., Inc., 1955, ix + 666 pp. $9.50.

Book is primarily designed for students as well as professorial chemical engineers interested in the fundamentals of mass transfer as applied to the design of various chemical engineering operations. The first five chapters are devoted to the general treatment of the basic laws governing diffusion in fluids and solids, illustrated with application problems and experimental data on mass, heat, and momentum transfer. Molecular diffusion, turbulent diffusion of fluids in the boundary layer, diffusion of gases into solids including porous solids, and the mass diffusion between two insoluable phases are treated with some generality.

The rest of the book is devoted exclusively to operational methods and analysis pertaining to chemical engineering processes involving mass and heat transfer. Part II deals with gas-liquid operations as applied to the design of various "phase-dispersion" equipment. Humidification and its thermodynamic principles, absorption of one or more components of a gas by a liquid in single- or multistage operations are followed by discussions on phase equilibrium of ideal and nonideal solutions as applied to the distillation processes.

Part III deals with the study of industrial methods used for extraction of liquids from a mixture of two soluble or insoluble liquids. Problems are solved involving single- or multistage extraction.

Solid and fluid adsorptions are discussed in part IV with general concepts of equilibrium, adsorption hysteresis, and heat of adsorption. Operations for single-component adsorption, fractionation, and percolation and their associated equipment are also presented. Heat and mass transfer are combined for solution of industrial drying problems. Leaching processes used for extraction of one or more constituents of a solid mixture by contact with a liquid solvent as applied to industrial uses are described.

The last part of the book describes briefly the less conventional operations such as dialysis, electrodialysis, atmolysis, and thermal diffusion.

The text was compiled for a course in mass-transfer operations with a primary purpose of giving chemical engineers the basic foundation for the design and operation of chemical processes and equipment dealing mainly with mass transfer.

S. Eskinazi, USA

Combustion

(See also Revs. 223, 266, 276)

Book—307. Proceedings of the gas dynamics symposium, August 22, 23, 24, 1955, Evanston, Ill., Northwestern Univ. 1956, 284 pp.

This is a collection of twenty-six papers related to current fundamental problems in combustion. These papers are grouped into the following categories: (1) Combustion of condensed phases; (2) nonsteady combustion; (3) laminar flames; (4) turbulent combustion;

(5) flame stabilization; and (6) detonation and thermodynamics.
M. Baker, USA

308. Feilden, G. B. R., Thorn, J. D., and Kemper, M. J., A standard gas turbine to burn a variety of fuels, *Inter. Shipbldg. Progr.* **3,** 24, 415-433, Aug. 1956.

309. Craig, O., and Smith, E. H., Burning fluid coke, ASME Semiann. Meet., Cleveland, O., June 1956. Pap 56-SA-63, 11 pp. + 3 tables + 8 figs.

Fluid coke is the secondary product of a process designed by Esso Research and Engineering Co. for making gasoline. In this process, preheated seed coke comes in contact with raw preheated feed stock in a reactor. The lighter fractions produced are flashed off and additional coke is formed. The accumulating coke reservoir is tapped off and is available as boiler fuel or for specialized products. A typical analysis of fluid coke is fixed carbon 94.1%, volatile matter 5.9%, size thru 50 mesh 70.0%. The ash content is usually less than 0.5%. The reactivity temperature of fluid coke is lower than that of metallurgical coke.

To burn fluid coke it is essential to bring its particles up to the ignition temperature (1400 F) and maintain it. This can be done by high initial temperatures of the coke and air mixture. In a Riley 50 Series pulverizer, temperatures of 400 F of the primary air and coke stream have been maintained without difficulty. A multinozzle type of burner (Riley Directional Flame Burner) and its application to opposed firing in the bottom of a special type of boiler furnace are described.

Charateristics of burning fluid coke are : high primary air temperature and fast heating of the coke particles by the radiant heat from the flame. Efficiency can further be increased by reinjection from the dust collector. The opposed firing inclined downward produces a stable flame and is effective in burning fluid coke with low excess air and very low carbon loss. Detailed results of a boiler test at Carbide and Carbon Chemical Corp. are given.

The appendix includes a discussion of grindability determination.
A. Erdely, Switzerland

310. Comerford, F. M., Combustion of carbon particles in luminous flames, *Fuel* **35,** 3, 333-342, July 1956.

In order to obtain information on the rate of combustion of carbon particles in luminous flames, the shape of the luminous soot zone and the variation of the spectral emissivity along the length of a preheated propane-air diffusion flame burning in hot surroundings have been studied. The air supply to the flame was controlled and the ratio of the air flow to that required for complete combustion was found to be far more important in determining the length of the soot zone than the relative velocities of the air and gas streams. The emissivity measurements can be explained by assuming that the reaction rate of air and soot particles is fast compared with the diffusion rate of the air, so that the latter determines the shape of the soot zone.

From author's summary

311. Cautius, W., Experiences in horizontal cyclone firing (in German), *Brennstoff-Wärme-Kraft* **8,** 6, 284-290, 1956.

Recently, cyclone firing has become more and more attractive in Germany. On May 1955 there were in service 38 cyclone boiler units of 2-3-m diameter. Author has made clear the relations between critical grain size of fuel, pressure loss, and rotating velocity of the flow of vortex in the tangentially fired cyclone furnace.
M. Kunugi, Japan

312. Barrere, M., Moutet, A., and Sarrat, P., Combustion instability in rocket motors. An experimental study (in French), *ONERA Publ.* 82, 66 pp., Mar. 1956.

Authors review experimental techniques applied to the study of combustion instability, treating, especially, instantaneous response devices together with current types of combustion chambers now being used. Methods described include measurements of chamber pressure, temperatures, propellant flow rate, and velocities in combustion chambers. Characteristics of combustion chambers used in studies of instability phenomena are also given.

Low-frequency instability is studied and phenomena observed are fully described, with particular emphasis on pressure stability of chamber, length, injection over pressure, nature of propellant, and mixture ratio. High-frequency instability is also studied with particular attention to the influence of chamber and exhaust nozzle.

Comparison of theoretical and experimental results is made. Authors confirm L. Crocco's theory, provided chamber pressure remains constant. Important discrepancies appear when pressure varies.
R. Delbourgo, France

313. Meagher, R., Johnson, R. L., and Parthemore, K. G., Correlation of engine noises with combustion phenomena, *SAE Trans.* **63,** 481-491, 1955.

314. Sturgis, B. M., Knock and antiknock action, *SAE Trans.* **63,** 253-264, 1955.

315. Lees, B., An investigation into the air-heater corrosion of oil-fired boilers, *J. Inst. Fuel* **29,** 183, 171-175, Apr. 1956.

Acoustics

(See also Rev. 160)

316. Skeib, G., Sound propagation in atmospheric turbulence (in German), *Z. Meteor.* **9,** 8, 225–234, Aug. 1955.

Sound intensity measurements were carried out in the space between two tall radio towers. Because a complete set of permanent meteorological instruments was stationed in this region, all data as to temperatures, wind velocity, relative humidity, etc., were constantly recorded. Frequencies used covered the range 100 to 4000 cps over distances from 50 to 150 m at either 5 m or 30 m above ground.

As an example: Turbulent wind caused a damping of 13 db when the receiver was 150 m away and the wind velocity greater than 5 mps. For 3 mps and the same frequency (3000 cps) the damping dropped to about half.

All data and graphs are based on statistical values and the results indicate the magnitude of the dependency of frequency and wind velocity. Paper is more a preliminary report on the general method, and further data will be reported later on, according to the author.
M. Rand, Canada

317. Guth, W., Sound conduction in metal rods (in German), *Acustica* **5,** 1, 35–43, 1955.

By means of the integration method of "stationary phase," a theory of the propagation of impulses and similar sounds in a dispersive medium is developed and demonstrated on a circular metal cylinder. The theory is compared with experimental data obtained by schlieren methods. The possible use of these results to explain the formation of ripples on steel rails is discussed.

From author's summary by J. S. Marcus, USA

318. Awatani, J., Anomalous behavior of Rayleigh disk for high frequency waves, *J. acoust. Soc. Amer.* **28,** 2, 297–301, Mar. 1956.

The behavior of the Rayleigh disk whose size cannot be neglected in comparison with the wave length is investigated. Results obtained are as follows. The sensitivity of the disk set to an angle 45° increases with the frequency of sound and reaches a maximum at the frequency corresponding to $k\ (=2\pi a/\lambda) \cong 1.6$ (a radius of the disk, λ wave length of sound). This maximum value is about 50% larger than that calculated from the König's ex-

pression. When k becomes larger than 1.6 however, the sensitivity begins to fall off and its sign, at last, changes to negative when $k \cong 4.5$. In the high-frequency region, the negative torque acts on the disk if the angle between its axis and the wave normal is small, but the positive torque if the angle is large. The disk displays the greatest sensitivity at an angle different from the ordinary angle 45°.

From author's summary

319. **Liamshev, L. M., Nonspecular reflection of sound from thin bounded plates submerged in a liquid** (in Russian), *Acta Phys. Hung. Budapest* **6**, 1, 33-65, 1956.

Discovery is made of a nonspecular ultrasonic reflection from thin finite plates under water, occurring at considerably smaller angles of incidence than that due to coincidence effect in bending. Precise measurements made in the Fraunhofer zone of reflection, using metal plates up to 1.1 mm thick and up to 6 × 6 cm, with megacycle sound waves, show this phenomenon to occur when the phase velocity of the incident waves along the plate is equal to the speed of longitudinal waves in the plate. A detailed theoretical analysis is made of sound diffraction, taking into account this plate response. The theory appears to describe the observed results satisfactorily.

W. W. Soroka, USA

320. **Corcos, G. M., and Liepmann, H. W., On the transmission through a fuselage wall of boundary layer noise,** *Douglas Aircr. Co. Rep.* SM-19570, 51 pp., Dec. 1955.

The noise intensity in the cabin is found to depend on dimensionless parameters involving the ratio of the boundary-layer characteristics and the plate characteristics of the cabin structure. Locally homogeneous turbulent boundary layer over a flat plate as an idealized fuselage cabin is assumed. Many other necessary simplifications are adopted. The basic mechanism analyzed is that the boundary-layer fluctuations excite plate oscillations which, in turn, induce sound oscillations in the air on the cabin side of the plate. Both of the two coupled systems are assumed linear. Limiting considerations of very thin and very thick boundary layers indicate that the mean pressure intensity of cabin noise depends little on the boundary-layer thicknesses, but rather strongly on free-stream air speed and density according to different power laws. The deduction of the dimensionless similarity parameters is of great importance in undertaking tests for design purposes.

S.-I. Cheng, USA

321. **van den Eijk, J., and Kasteleyn, M. L., A method of measuring flanking transmission in flats,** *Acustica* **5**, 5, 263-266, 1955.

Paper is concerned with the sound insulation between two rooms and reports investigations carried out in flats in Rotterdam. It is shown that airborne sound vibrations in the source room set the floor between two rooms into vibration as well as the walls of the source room and the latter vibrations are transmitted to the walls of the receiving room. As a result, both floor and walls of receiving room radiate sound energy into that room. The method described to determine influence of flanking transmission on airborne and impact sound insulation assumes that airborne sound insulation over more than one story is due to flanking transmission only, and the insulation due to flanking transmission between two rooms directly above each other can be determined by subtracting from the insulation over two stories, the damping of the flanking transmission per story.

Experimental investigations indicate that, for the lighter of the two floors, an improvement in the floor construction will be profitable, whereas for the heavier floor, the possibilities of the low frequencies are limited due to flanking transmission.

S. K. Ghaswala, India

322. **Anderson, A. B. C., Metastable jet-tone states of jets from sharp-edged, circular, pipe-like orifices,** *J. acoust. Soc. Amer.* **27**, 1, 13-21, Jan. 1955.

Characteristics of spectra from relatively thick orifices differ from those from relatively thin orifices. In a given range of Reynolds number, in many cases the jet may exist in any one of several reproducible jet-tone states (metastable states) characteristic of the orifice. The dependence of the component frequencies of the jet-tone spectra (expressed in terms of the orifice number $fd/(\Delta p/\rho)^{1/2}$) on Reynolds number $[pd(\Delta p/\rho)^{1/2}]/\mu$ is shown, where d is diameter of orifice, f frequency, Δp pressure difference across orifice, ρ density, and μ viscosity of gas. The orifice numbers of the components of the jet-tone spectra generally tend to fall on a single array of equally spaced orifice-number levels. Jet-tones from the same orifice plate, characteristic of both thin as well as thick orifice plates, are found to coexist over a small transition range of orifice thickness-diameter ratio. If the orifice number of the head of the most probable spectral mode for a given orifice thickness-diameter ratio is noted, the same will be found again for the head of the most probable mode at approximate orifice thicknesses $t \pm nd$, where n is a small integer.

From author's summary.

323. **Schmey, J., and Guerke, R. M., Control of propeller noise in turboprop installations,** *SAE Trans.* **63**, 295-302, 1955.

324. **Fehr, R. O., and Crocker, B. E., Acoustic design and performance of turbojet test facilities,** *SAE Trans.* **63**, 284-288, 1955.

325. **Regier, A. A., Why do airplanes make noise,** *SAE Trans.* **63**, 275-283, 1955.

326. **Essers, I., Coupled vibrations on lorries** (in German), *Z. Flugwiss.* **4**, 5/6, 179-185, May/June 1956.

Fatigue fracture of the member joining the lorry and trailer has caused separation of the trailer and thus numerous fatal road accidents. In order to investigate the causes, shaft forces on lorry-trailer combinations have been analyzed. Comparative tests have shown that magnitude and frequency of shaft forces are governed not only by longitudinal oscillations, as generally assumed, but also by pitching oscillations of the vehicles.

From author's summary

Ballistics, Detonics (Explosions)

(See Revs. 63, 267, 286, 307, 312).

Soil Mechanics, Seepage

(See also Revs. 36, 37, 73)

327. **Rowe, P. W., The single pile subject to horizontal force,** *Géotechnique, Lond.* **6**, 2, 70-85, June 1956.

The value of the modified "coefficient of horizontal subgrade reaction" for a single pile in cohesionless soil, called the soil-stiffness modulus, is found to depend on the flexure and geometry of the pile. The form of the relation between the modulus for a pile of width B and that for a continuous wall is estimated from ϕ_m-mobilization theory and is found to correspond with available test data. A procedure for estimating the load/deflection curve for a pile is proposed which takes account of the properties of the soil and the pile and the relation between these properties.

From author's summary by A. W. Skempton, England

328. **Yang, N.-C., Redriving characteristics of piles,** *Proc. Amer. Soc. civ. Engrs.* **82**, SM3 (*J. Soil Mech. Found. Div.*), Pap. 1026, 20 pp., July 1956.

In evaluating the bearing capacity of a pile, the present tech-

nique still can be improved. The temporary stress adjustments in the subsoil after pile driving have effects which to some extent invalidate the application of pile driving formulas. For pile loading tests, the excessive expense often prevents the determination of all quantitative information necessary for conclusive interpretation. The purpose of this paper is to present the results of observations made during the redriving of piles and to discuss their possible applications. From author's summary

329. Proceedings of the European conference on the stability of earth slopes: Session 4, 5, 6, *Géotechnique, Lond.* **5,** 2, 226 pp., June 1955.

The proceedings consist of eleven papers and their discussions, nine papers being in English and two in French.

Six papers contain descriptions of landslides, field and laboratory investigations related to them, their probable causes, and the remedial measures. They describe shallow slides in overconsolidated clay, slides in clay containing thin lenses of silt and sand, slides associated with tectonically disturbed beds containing broken and weathered materials, and a slide in a thin layer of peat brought about by rise in water pressure.

One paper describes an interesting method of locating thin layers of sand and silt in clay banks by obtaining continuous record of shear strength in two bore holes by means of a shear-strength-in-situ device. In one hole the record is taken in dry season, and in the other, in wet. The shear strength of sand layers comes out greatly different in the two holes due to the difference in water pressure, while the shear strength of clay is not materially affected by the season.

Four papers of theoretical nature deal with stability of upstream and downstream slopes in earth-fill dams; laboratory investigation of the time effect with regard to the magnitude of the neutral pressure in soil of low permeability; the use of the chemical method called "hydroton" for increasing greatly the permeability and improving the shear strength of the soil material to be used in an earth-fill dam; and a theoretical investigation of stresses in the downstream part of a dam.

A. Hrennikoff, Canada

330. Clevenger, W. A., Experiences with loess as foundation material, *Proc. Amer. Soc. civ. Engrs.* **82,** SM3 (*J. Soil Mech. Found. Div.*), Pap. 1025, 27 pp., July 1956.

Certain characteristic properties governing the behavior of loess as a foundation material have been defined through extensive laboratory and field studies conducted by the Bureau of Reclamation. These studies were primarily limited to the loess or loess-like materials occurring in the Missouri River Basin of central western United States. In this paper, broad generalizations of many pertinent properties of loess are presented and their significance is pointed out by discussions of specific typical experiences with loess as foundation material. Some interesting data gathered by the writer on residence foundation failures in Colorado are described, as well as results of laboratory and field studies of the properties of the loess connected with these failures. From author's summary

331. Nerpin, S. V., Equilibrium between the filmy and capillary moisture in clayey soils (in Russian), *Izv. Akad. Nauk SSSR Otd. tekh. Nauk* no. 5, 50–54, May 1955.

From the fact that total energy at any point of a viscous liquid can be expressed as a function of the equilibrium of film and capillary moisture, author develops relation of moisture content of soil to volumetric forces, using concept of wedged pressure. Experiments with centrifuged samples confirm equation.

V. L. Dutton, Canada

332. Postlethwaite, J. D., The measurement of soil moisture, *agric. engng. Res.* **1,** 1, 89–95, 1956.

333. Gillette, H. S., Preparing base-course materials for disturbed-soil indicator tests, *Highway Res. Board Bull.* **122,** 1-, Jan. 1955.

Micromeritics

(See also Revs. 150, 152, 188)

334. Kidder, R. E., Flow of immiscible fluids in porous media; exact solution of a free boundary problem, *J. appl. Phys.* **27,** 8, 867-869, Aug. 1956.

A mathematically exact solution is presented for the two-dimensional free boundary problem arising in the flow of two immiscible fluids in porous media. The particular problem dealt with concerns the "fingering" of water toward an infinite line of equally spaced oil wells, each pumping at the same rate, from a thin, inclined, permeable stratum.

The solution is obtained by use of complex variable theory and the hodograph plane. G. A. Leonards, USA

335. Crausse, E., and Poirier, Y., Analogy study of infiltration in anistropic media with the aid of conducting paper analogy (in French), *C. R. Acad. Sci. Paris* **243,** 5, 475-477, July 1956.

336. Salekhov, G. S., Statement of and methods for the solution of hydrodynamic problems in the control of oil-bearing strata circumference (in Russian), *Dokladî Akad. Nauk SSSR (N. S.)* **101,** 5, 809-812, 1955.

337. Pramanik, H. R., Particle size determination through settling processes, *J. Instn. Engrs., India* **36,** 8, part 1, 1674-1682, Apr. 1956.

Geophysics, Meteorology, Oceanography

(See also Revs. 42, 316, 352)

338. Matuzawa, T., Reflection and refraction of seismic waves (in German), *Bull. Earthq. Res. Inst., Tokyo Univ.* **33,** part 4, 543-548, Dec. 1955.

Reflection and refraction of elastic waves (SH-waves) caused by a heterogeneous layer is discussed. This may be applied to the analysis of the reflected phase in seismic prospecting.

Assume a layer in which density is constant, but the velocity changes linearly in the direction perpendicular to the boundary. In place of this medium, an infinite number of thin layers, every one of which is homogeneous, is assumed. Outside this layer the media are assumed homogeneous.

Direction of the wave propagation is assumed nearly perpendicular to the boundary surfaces and the square terms of direction-cosines are neglected compared with unity. This is an adequate approximation when we think of the case of reflected waves in explosion seismology.

Into the ordinary boundary conditions (continuity of displacement and stress) which must hold at every boundary surface between thin layers, the above assumption is introduced and the expressions are simplified. Thus the integral representations of the amplitude of reflected and refracted waves are obtained.

By a simple numerical example author shows that the reflected amplitude is dependent upon the ratio of the thickness of the layer to wave length. Y. Sato, Japan

339. **Gifford, F., Jr., The relation between space and time correlations in the atmosphere,** *J. Meteor.* **13,** 3, 289-294, June 1956.

Paper presents derivation of equation for Eulerian velocity-time autocorrelation function valid for all intensities of turbulence. Derivation is based on analysis by Ogura [*J. meteor. Soc. Japan*, **31**, 355-369, 1953; ibid, **33,** 31, 1955], from which autocorrelation function is obtained as an unevaluated definite integral. Author evaluates integral by transforming to fractional-order Bessel functions and replacing these by equivalent contour-integral expressions; the latter are evaluated with help of published integral transform tables. Result is given in terms of hypergeometric functions, but it is shown that, if argument (time lag) of correlation function is not too large, the solution may be approximated by a small number of terms involving gamma-functions with numerical arguments together with the intensity of turbulence and the frequency of the dominant Fourier component as the physical parameters. For low intensities of turbulence, the correlation $R(t)$ is proportional to $t^{2/3}$, in agreement with well-known Taylor hypothesis that time and space correlation functions are related by transformation $x = Ut$, where x is argument of space correlation function and U is mean flow velocity. For values of turbulent intensity in atmospheric range the deviation from 2/3-power law is quite small, justifying use of Taylor transformation in study of atmospheric turbulence. Derived correlation function is compared with experimental data on both mesometeorological and synoptic scales; agreement is excellent for the smaller scale and good for the larger scale.

Reviewer regards work valuable in providing more rigorous basis for Taylor hypothesis and thereby facilitating use of time-series data records in experimental study of atmospheric turbulence. E. W. Barrett, Sweden

340. **Dufour, L., Thermodynamical study of the entrainment of air into a cumulus,** *Tellus* **8,** 2, 202-205, May 1956.

Older descriptions of the nature of clouds treated them as entities which did not mix with their surroundings; that is, as closed thermodynamic systems. In the last ten years it has become more apparent that air from outside the cloud does mix into it, or becomes entrained into it, to use the expression currently favored.

Author has attempted to put the theoretical description of this entrainment on a sounder basis than it has had heretofore. He does this by considering the cloud as an open rather than a closed thermodynamic system. The principal result is an expression for the change of cloud temperature as it ascends in the atmosphere, or, alternatively, as the pressure of its environment changes. Author shows that older results are special cases of his more general result.

Reviewer believes results should be of value to meteorologists in explaining observed cloud temperatures. Other applications might lie in treatment of similar problems of mixing of jet of air or steam with its environment. F. I. Badgley, USA

341. **Frenkiel, F. N., Atmospheric pollution with application to Los Angeles area,** 1955 Heat Transfer and Fluid Mech. Inst., Los Angeles, Univ. of Calif., June 23-25, 1955, Pap. 15, 14 pp.

Author reviews the problem of atmospheric pollution caused by emission to the atmosphere of many impurities resulting from human activities and the transport of these impurities away from the point of origin. An important consideration is the meteorological factors affecting this transport, and the turbulence of the atmosphere. This turbulence can be studied as a problem in fluid dynamics using equations for wind-tunnel effects and making certain assumptions in order to apply these equations to atmospheric conditions.

Electronic computers can be used to process a sufficiently large mass of data to achieve statistical significance. A mathematical model can then be constructed to define pollution conditions on an area-wide basis, taking into consideration the distribution of sources and emission conditions, micrometeorological factors, and topography. With simplifying assumptions, it is then possible to define pollution levels as a function of time and analyze the relative contributions of individual sources to the local contamination at various points in the area. As an example, theoretical curves are shown for the Los Angeles Basin, both with and without correction for photochemical effects, as a function of time of day. Agreement with measured levels of oxidant concentration is encouraging. H. McKee, USA

342. **Plass, G. N., Effect of carbon dioxide variations on climate,** *Amer. J. Phys.* **24,** 5, 376-387, May 1956.

Variations in the amount of atmospheric carbon dioxide cause temperature changes sufficiently large to influence the climate. If the atmospheric carbon dioxide doubles, the surface temperature rises 3.6 C; if it is cut in half, the surface temperature falls 3.8 C. Some of the factors that can be explained by the carbon-dioxide theory are: During a single glacial epoch, the climate continually oscillates between a glacial and an interglacial stage with a period of tens of thousands of years with no stable state possible, when the carbon dioxide amount is below a certain critical value; the increased precipitation at the beginning of a glacial period; the time lag between the period of mountain building and the onset of glaciation; periods of glaciation occur at the same time in both hemispheres; the general warming of the climate in the last fifty years. The various factors that enter into the carbon-dioxide balance and the influence of the oceans on the atmospheric carbon-dioxide amount are discussed in detail. In contrast to other theories of climatic change, the carbon-dioxide theory predicts a warming trend that will continue for centuries, or as long as fossil fuels are burned in significant quantities.

From author's summary

343. **Plass, G. N., The carbon dioxide theory of climatic change,** *Tellus* **8,** 2, 141-154, May 1956.

The most recent calculations of the infra-red flux in the region of the 15 micron CO_2 band show that the average surface temperature of the earth increases 3.6° C if the CO_2 concentration in the atmosphere is doubled and decreases 3.8° C if the CO_2 amount is halved, provided that no other factors change which influence the radiation balance. Variations in CO_2 amount of this magnitude must have occurred during geological history; the resulting temperature changes were sufficiently large to influence the climate. The CO_2 balance is discussed. The CO_2 equilibrium between atmosphere and oceans is calculated with and without $CaCO_3$ equilibrium, assuming that the average temperature changes with the CO_2 concentration by the amount predicted by the CO_2 theory. When the total CO_2 is reduced below a critical value, it is found that the climate continuously oscillates between a glacial and an interglacial stage with a period of tens of thousands of years; there is no possible stable state for the climate. Simple explanations are provided by the CO_2 theory for the increased precipitation at the onset of a glacial period, the time lag of millions of years between periods of mountain building and the ensuing glaciation, and the severe glaciation at the end of the Carboniferous. The extra CO_2 released into the atmosphere by industrial processes and other human activities may have caused the temperature rise during the present century. In contrast with other theories of climate, the CO_2 theory predicts that this warming trend will continue, at least for several centuries.

From author's summary

344. **Fonselius, S., Koroleff, F., and Warme, K.-E., Carbon dioxide variations in the atmosphere,** *Tellus* 8, 2, 176-183, May 1956.

The Scandinavian CO_2-sampling in 1955 is described. Mean results for the calendar year are given. Earlier CO_2-measurements

are discussed and a figure showing most of these values is given. Theory of Callendar is discussed and Scandinavian values are compared with Callendar's. Seasonal variations at the Scandinavian stations are compared and the results discussed. The possibility of drawing synoptic maps is discussed and one example is shown. The desirability of systematic CO_2-measurements on global scale is emphasized. From authors' summary

Lubrication; Bearings; Wear

345. Bowers, R. C., Cottington, R. L., Thomas, T. M., and Zisman, W. A., Friction and wear studies of chlorinated methylphenyl silicones, *Indust. Engng. Chem.* **48,** 5, 943-950, May 1956.

Friction and wear characteristics of chlorinated methylphenyl silicones with three different amounts of chlorine attached to the phenyl group are compared with an unchlorinated methylphenyl silicone and a nonadditive petroleum oil. The chlorinated silicones showed a reduction in friction over the unchlorinated silicone, particularly for higher sliding speeds and for hard steel sliding on hard steel and steel sliding on copper. This improvement was not as marked for hard steel on soft steel. Wear tests on a four-ball wear machine indicated a reduction in wear rate with increased chlorine content. However, even the most highly chlorinated silicone was less effective than the nonadditive petroleum oil, indicating that, even with chlorine present in the molecule, silicones are poor boundary lubricants, particularly when a hard-steel member slides on a soft-steel member.

M. C. Shaw, USA

346. Bidwell, J. B., and Williams, R. K., The new look in lubricating oils, *SAE Trans.* **63,** 349-361, 1955.

Marine Engineering Problems

(See also Revs. 167, 168, 171)

347. Khaskind, M. D., Approximate methods for the determination of the hydrodynamic characteristics of ship oscillations (in Russian), *Izv. Akad. Nauk SSSR Otd. tekh. Nauk* no. 11, 66-86, Nov. 1954.

Paper is an attempt to summarize and to complete author's earlier theoretical and experimental work on ship oscillations [title source no. 7-8, 1942, no. 11-12, 1942, no. 10, 1946; *Prik. Mat. Mekh.* **10,** 1, 1946, **17,** 2, 1953, **17,** 3, 1953, **18,** 1, 1954]. Vertical and lateral translatory oscillations and rotations about all three ship axes are considered. As an approximation, the hydrodynamic forces and moments on an oscillating ship hull, which is moving obliquely against plane sinusoidal waves, can be divided into three groups. The first group contains forces and moments due to forced oscillations of the ship in translatory motion on a calm water surface, and in the second there are the well-known restoring moments and forces due to the static stability and buoyancy of the ship. The third group comprises disturbing forces and moments caused by waves on a nonoscillating hull in steady motion, and can be divided into two classes, the first of which consists of forces which are caused by undisturbed waves, and the second of forces caused by wave diffraction.

The first group of forces and moments is characterized by the generalized coefficients of the entrained mass and of damping. They depend on the frequency of forced oscillations of the ship, but are nearly independent of the traveling speed for sufficiently slender hull forms. Using certain theoretical results of his earlier work and assuming simplified forms for ship sections, author derives approximate expressions for these coefficients in the case of inifinitely slender hulls and indicates how the finite hull length can be taken into account.

The disturbing forces and moments due to waves without taking into account wave diffraction can be determined by the theory of A. N. Krylov. Earlier obtained forms for the velocity potential allow derivation and discussion of approximate formulas for these orces and for those caused by wave diffraction as well.

A. Kuhelj, Yugoslavia

348. Sims, A. J., and Williams, A. J., Ship motion and vibration. The pitching and heaving of ships, *Shipbuilder* **63,** 576, 27-275, Apr. 1956.

349. Corlett, E. C. B., On design of economic tramp ships, *Trans. Instn. nav. Arch. Lond.* **98,** 2, 173-201, Apr. 1956.

Paper outlines some of the background of development of the modern tramp ship and illustrates its emergence. An analysis of some economic and technical characteristics of the modern tramp ship is then given together with a discussion of particular features which influence these and their relationship.

Suggestions are made for some features which it is submitted could be included with advantage in such ships, and the final section of the paper shows design proposals for several types of ship capable of engaging economically in different categories of tramping work.

From author's summary

350. Henry, J. J., Design of ships. Modern ore-carriers, *Shipbuilder* **63,** 576, 231-238, Apr. 1956.

351. Friswell, J. K., Kurn, A., and Ridland, D. M., Investigation of high length/beam ratio seaplane hulls with high beam loadings. Hydrodynamic stability, Part 2: The effect of changes in the mass, moment of inertia and radius of gyration on longitudinal stability limits, *Aero. Res. Counc. Lond. curr. Pap.* 202, 14 pp. + 20 figs., 1955.

Tests have been performed to ascertain the effects of varying load, moment of inertia, and radius of gyration on the stability limits of a high length-to-beam-ratio dynamic model. The tests were carried out at high beam loadings, with C_{Δ_0} in the range 2.00-3.00. A theoretical analysis has been made of the relation between the effects of the various parameters, and the results of the analysis compared with experimental results. The effect on the limits of a change from a velocity to a draught base has also been considered.

It has been found that the load is the most critical factor, and that, provided the load is kept constant, increasing the moment of inertia has little effect on the limits. Good agreement has been found between theoretical treatment and experiment.

From authors' summary

352. Pierson, J. D., and Carver, C. E., Jr., Hope for rational seaplane design, *Aero. Engng. Rev.* **14,** 12, 26-30, Dec. 1955.

Authors review briefly certain recent developments in oceanography and ship motions and suggest that studies of waves, currents and meteorological conditions affecting the sea will provide the designer of water-based aircraft with reliable means to analyze open sea water loads and, therefore, with a more rational approach to the structural design of such craft from both the standpoint of fatigue as well as maximum load. Paper is descriptive.

M. St. Denis, USA

353. Davis, A. W., Marine reduction gearing, *Inter. Shipbldg. Progr.* **3,** 19, 134-162, Mar. 1956.

354. Kostyukov, A. A., Velocity potential and wave resistance of ships in limited water depths (in Russian), *Izv. Akad. Nauk SSSR Otd. tekh. Nauk* no. 9, 50-62, Sept. 1954.

The question of wave resistance of a slender ship in shallow water was first attacked by J. H. Michell, 1898 [*Phil. Mag.* **45**] and independently by N. E. Zhoukovskiy, 1903 [Compl. Works (in Russian) vol. IV, 1937]. Michell gave a partial solution of the problem concerning some reasonings about the case of long waves. Zhoukovskiy solved the case of a vessel having a cylinder-shaped shell reaching to the water bottom; he also determined the shape of minimum resistance for that case.

The problems of the velocity potential and wave resistance of a slender ship in a limited channel was resolved in 1936, using different methods, by M. V. Keldysh and L. I. Sedov [Trudy Konf. Voln. Sopr. (in Russian) C.A.G.I., 1937]; and by L. N. Sretenskiy [Trudy C.A.G.I. (in Russian) v. 319, 1937]. M. V. Keldysh and L. I. Sedov resolve the problem by the Fourier method, deducing first the formulas for a given surface-pressure distribution which moves with constant velocity. They then give rules for their application to the computation of the wave resistance of a ship. L. N. Stretenskiy solved the problem by means of theory of potential with use of the dissipative-forces method.

M. D. Haskind [*Prikl. Mat. Mekh.* (in Russian), **9**, no. 3, 1945] could, by means of theory of potential, deduce formulas for the velocity potential and for the wave resistance due to a body of arbitrary shape, moving *beneath* the surface of a liquid of finite depth.

In the present work, author gives a new method of deduction of the velocity potential past a slender ship in shallow water, based on the generalized Fourier transformation. Also, he gives an expression for the velocity potential for a body of arbitrary shape moving beneath the free surface of the liquid.

Author claims the given expression for the velocity potential may be more practical than existing ones, for a series of problems; e.g., for calculation of free-surface ordinates past a ship, calculation of the hydrodynamic lift, etc.

Also author analyzes the difference in the decay of wave amplitude afore and astern the ship. Some hints are given about the practical calculation of wave resistance using Havelock's formula [*Proc. Roy. Soc. Lond.* (*A*), **118**, 1928 and **144**, 1934], where author's method of determination of wave profile at great distance from ship, author claims, will save important difficulties.

An expression for wave resistance of *propellers* in shallow water is also given (deduced by means of sink distribution).

Author compares all his formulas with formulas by others and with measurements. A list of references (mainly in Russian) is given.

From author's summary (a little enlarged) by
N. Krivoshein, Argentina

355. Ridgely-Nevitt, C., Turbulence stimulation of a single screw tanker model, *Inter. Shipbldg. Progr.* **1**, 4, 224–229, 1954.

It must be realized that the following conclusions are applicable only to this particular model, one on which it is very difficult to achieve fully turbulent flow.

(1) Sand is not a successful stimulator at water temperatures of 72F or lower. Only by means of extensive trial-and-error arrangements of the sand was one configuration discovered that appears fairly satisfactory.

(2) The one arrangement involved consisted of ½ in. wide strips down the stem, along the load waterline for 20% of the length, and around the station line at 0.2L.

(3) Stimulation is most easily achieved by means of increasing the water temperature and, thereby, raising the Reynolds number.

(4) The "turbulence level" in the tank has a small but measureable effect on resistance in the transitional flow region, whether other turbulence stimulation is present or not.

(5) No attempt should be made to correct for trip wire drag.

(6) Further work on this model should be undertaken, when time is available, with stimulators other than sand, and at tank temperatures higher than the 72F value used here.

From author's summary

356. Horn, F., Determination of mean wake from propulsion and open tests, *Inter. Shipbldg. Progr.* **3**, 21, 243–254, May 1956.

Traditional effective wake determination since R. E. Froude is based on thrust identity at equal number of revolutions of the ship propeller in open water and in the inhomogeneous flow behind the ship's hull. In principle, the wake fraction can also be determined by torque identity. The results of both methods are slightly different, and in the United States there is preference to use their mean value. By application of the principle of "virtual velocities," author attempts to give a rigorous solution of the wake problem. His results are for all practical purposes identical to the mean value of thrust and torque effective wake fractions.

L. Troost, USA

357. Lap, A. J. W., Frictional drag of smooth and rough ship forms, *Quart. Trans. Instn. nav. Arch. Lond.* **98**, 2, 137–172, Apr. 1956.

Author develops a new method of correlating the resistance coefficients of pipes and rectangular flat plates. Since plate friction coefficients cannot be applied to ship forms, a new refined calculation system is outlined for determining frictional resistance for these shapes.

J. B. Duke, USA

358. Jasper, N. H., and Birmingham, J. T., Sea tests of the USCGC Unimak. Part 1–general outline of tests and test results, *David W. Taylor Mod. Basin Rep.* 976, 37 pp., Mar. 1956.

359. Szebehely, V. G., and Todd, M. A., Ship slamming in head seas, *David W. Taylor Mod. Basin Rep.* 913, 72 pp., Feb. 1955.

Maximum speed of a surface vessel in a rough sea depends not upon its power but upon its behavior in the seaway. The most violent attack of the sea on a vessel is probably the heavy blow delivered by the water on the re-entering bow. The ship vibrates after the impact and plates under the fore foot may be damaged. Slamming is the term used to describe this hydrodynamic impact phenomenon. It is associated with a sudden change of acceleration of the ship. Initial theoretical studies of slamming were made by V. G. Szebehely [AMR **5**, Rev. 3606].

In this paper the hydrodynamics, the kinematics, and the effects of slamming are discussed. Present methods of ship-motion prediction are used to study the conditions which lead to slamming of ships in head seas. An iterative procedure is described to estimate slamming force, acceleration, and pressure distribution on the bottom of a slamming ship.

F. E. Reed, USA

360. Todd, M. A., Slamming due to pure pitching motion, *David W. Taylor Mod. Basin Rep.* 883, 31 pp., Jan. 1955.

Theoretical predictions of maximum slamming forces experienced by a ship's hull when its impact with the free water surface is due to pure pitching motion are compared with results from a series of experiments on a model. The model is given an initial angular displacement about a fixed axis of rotation, located about 30% of the length from the stern, and allowed to pitch in its natural period. Pressure distribution over some of the forward sections is obtained theoretically. The region of maximum pressure is about 20% of the length behind the bow. Effect of slamming in the pitching motion is shown to be slight. Speeds of advance of the artificially pitched model have small effect on the slamming.

F. E. Reed, USA

361. Szebehely, V. G., and Lum, S. M. Y., Model experiments on slamming of a Liberty ship in head seas, *David W. Taylor Mod. Basin Rep.* 914, 20 pp., Feb. 1955.

Experimental results of motion studies and slamming are presented. A 5.5-ft model of a Liberty ship was tested in waves of varying length ($0<\lambda<9$ ft), of approximately constant wave-length/wave-height ratio ($\lambda/h \sim 20$), and with different thrusts (0.4 to 1.2 lb) at two draft conditions. Speed reduction, pitching angle, heave,

bow acceleration, and slamming acceleration are presented in the form of dimensional and dimensionless graphs. Two experiments are discussed in detail, showing recorded pitching angle, heave, bow acceleration, and keel emergence as well as computed resultant bow displacement, bow velocity, and vertical wave velocity. It is shown that slamming can occur in regular waves under properly selected conditions.

From authors' summary by F. E. Reed, USA

Letters to the Editor

362. Re AMR **9**, Rev. 1898 (June 1956): **Szablewski, W., Turbulent flow in divergent channels.**

The reviewer states that "mixing length distribution is arbitrary and has no fundamental importance", and draws the conclusion that investigations of turbulent boundary layers based on the Prandtl assumption cannot be taken as realistic. I consider this statement as lacking foundation, and would like to make two references to the present state of the research in the field. (1) Professor Burgers has just recently published an interesting study on "Some considerations on turbulent flow with shear" [AMR **7**, Rev. 205] in which he obtained the relationship for values close to the walls. $\tau \sim y^2 \left(\frac{du}{dy}\right)^2$ This equation was obtained by the Lagrangian approach; p. 146, Eq. 14. This result is in line with the Prandtl assumption. (2) As another proof that even in the U. S. at the present time the assumption of Prandtl is taken to be valid, I would like to refer to the *Journal of the Aeronautical Sciences* **21**, 404–410, and **22**, 255–260.

363. Re AMR **9**, Rev. 2492 (August 1956): **Hoppmann, W. H., II, New apparatus for study of deformation of clamped circular plate loaded with lateral pressure.**

In the above review the second-to-the-last sentence should read as follows: For these plates, (0.033 inch) agreement in the region of nonlinear large elastic deformations with the Way theory is perfect.

W. Soete, Belgium

Books Received for Review

ABBETT, R. W., edited by, American civil engineering practice, Vol. 1, xii + 1020 pp. + index. $15; Vol. 11, xiii + 917 pp. + index. $15, New York, John Wiley & Sons, Inc.; London, Chapman & Hall, Ltd., 1956.

Application of spring strips to instrument design. Notes on applied science, no. 15, National Physical Laboratory, Dept. of Scientific and Industrial Research, London, Her Majesty's Stationery Office, 1956, iv + 25 pp. 2s.

BENNETT, A. A., MILNE, W. E., and BATEMAN, H., Numerical integration of differential equations, New York, Dover Publications, Inc., 1956, 108 pp. $1.35 (paperbound).

BERKELEY, E. C., and WAINWRIGHT, L., Computers; their operation and applications, New York, Reinhold Publishing Corp., 1956, 366 pp. $8.

BIEZENO, C. B., and GRAMMEL, R., Engineering dynamics, Vol. 11. Elastic problems of single machine elements, London, Blackie & Son Limited, 1956, x + 527 pp. 90s.

BORG, S. F., An introduction to matrix tensor methods in theoretical and applied mechanics, Ann Arbor, Mich., J. W. Edwards, Publisher, Inc., 1956, 202 pp. $4.75.

BORKMANN, K., and OBERLANDER, S., Lösung des Allgemeinen Randwertproblems für Eindimensionale Gedämpfte Wellen Bei Harmonischem Zeitgesetz. (Schriftenreihe des Forschungsinstituts für Mathematik, Bei Der Deutschen Akademie der Wissenschaften zu Berlin). Berlin, Akademie-Verlag, 1955, 98 pp. DM 12.

CRANDALL, S. H., Engineering analysis, New York, McGraw-Hill Book Company, Inc., 1956, x + 417 pp. $9.50.

CZWALINA, A., Die Mechanik des Schiwimmenden Körpers, Leipzig, Akademische Verlagsgesellschaft Geest & Portig K.-G., 1956, 129 pp. DM. 12.

HAYWOOD, R. W., edited by, Thermodynamic tables and other data, New York, Cambridge University Press, 1956, 23 pp. $0.50.

HURST, R., and MCLAIN, S., edited by, Technology and engineering, Series IV, Vol. 1, (Progress in Nuclear Energy), New York, McGraw-Hill Book Co., Inc.; London, Pergamon Press Ltd., 1956, xiii + 420 pp. $12.

Ninth International congress of applied mechanics, (Section I. Fluid mechanics, 250 abstracts; Section II. Mechanics of solids, 240 abstracts) Brussels--1956.

PAI, S.-I., Viscous flow theory. 1. Laminar flow, Princeton, N.J., D. Van Nostrand Company, Inc., 1956, xvi + 384 pp. $7.75.

QUAK, K., Technisches Wissen: Technische Stoffe I—Aufbau der Materie Steine und Erden Holz, Kunstoffe, 3rd ed., Leipzig, Fachbuchverlag, 1956, xiii + 457 pp. + 1 chart. DM 18.

TEMPLE, G., and BICKLEY, W. G., Rayleigh's principle and its applications to engineering, New York, Dover Publications, Inc., 1956, 152 pp. $1.50 (paperbound).

TOWN, H. C., and COLEBOURNE, R., Engineering inspection, measurement and testing, New York, Philosophical Library, Inc., 1956, 192 pp. $8.75.

WARBURTON-BROWN, D., Induction heating practice, New York, Philosophical Library, Inc., 1956, 192 pp. $10.

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